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FEBRUARY 1955

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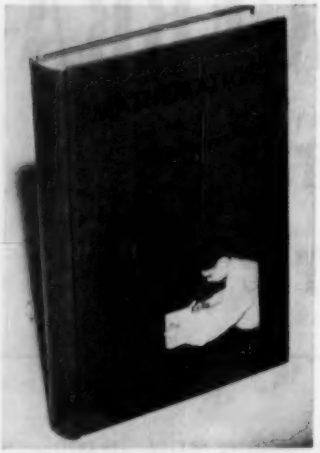

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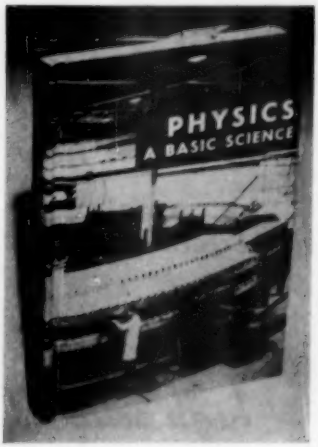

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CONTENTS FOR FEBRUARY, 1955

Modern Methods and Current Criticisms of Mathematical Education—*Maurice L. Hartung* 85

Designing a Basic Science Course for a Specific Situation—*W. C. Van Deventer* 91

Equation Balances—*Homer C. Torreyson* 104

Thinking Machines and Your Telephone—*Howard Bamman* 109

About the Scientific Method—*Sr. M. Roswitha* 120

The Evaluation Program in Secondary Mathematics—*William David Reeve* 123

Chicks are Good Teachers—*Jeannette Zabrocki* 141

Aluminum's Annoying Associate—*B. Clifford Hendricks* 149

Some Direct Uses for Square Root—*Alan Wayne* 153

Problem Department—*Margaret F. Willerding* 154

Books and Pamphlets Received 161

Book Reviews 162

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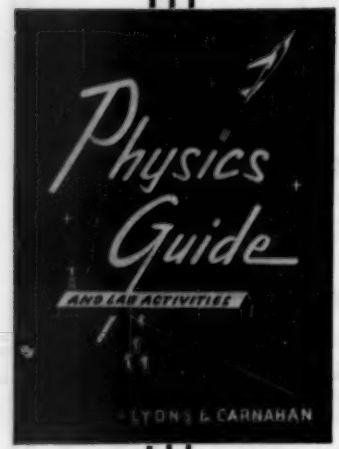

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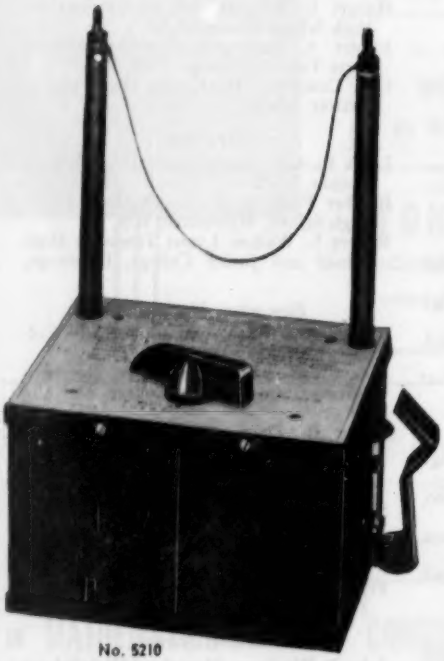

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SCHOOL SCIENCE
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VOL. LV FEBRUARY, 1955 WHOLE NO. 481

MODERN METHODS AND CURRENT CRITICISMS OF MATHEMATICAL EDUCATION*

MAURICE L. HARTUNG
The University of Chicago, Chicago, Ill.

We are teachers. Probably we are all aware that some highly critical statements are being made about teachers these days. Educationists—a special variety of teachers that I happen to represent—are accused of undermining the educational system by promoting the use of modern methods in the schools. Critics say we aren't teaching the right things. Critics say pupils aren't learning as much as they should learn. Critics say the conduct of pupils has greatly deteriorated. Some of us teachers are among the critics, and we may say these same things ourselves—but usually only within our own groups, and not publicly. We may also note that the three complaints I have just mentioned are general criticisms. They are not directed specifically at mathematical education.

Some critics, when they say we aren't teaching the right things, assert that "intellectual" subjects like foreign languages and mathematics are being neglected. They point to the great variety of subjects now found in the lists of courses available in larger schools. The list may include Art, Home Mechanics, Driver Education, Foods, Stagecraft, and many others. It is true that some of these courses, as they are usually taught, are less demanding of intellectual abilities than, for example, science and mathematics. We should, however, be fair enough to admit that sometimes mathematics also is taught at a very low intellectual level. Moreover, a good teacher with bright

* This paper constitutes the formal portion of an address at a general session of the annual convention of the Central Association of Science and Mathematics Teachers on Saturday, November 27, 1954.

pupils might choose to teach a so-called "non-intellectual subject" at a relatively high intellectual level.

Whether a school subject is more or less intellectual depends upon what happens in the minds of the pupils. This, in turn clearly depends upon their abilities and interests. It also depends upon the objectives deemed important by the teacher, and the teacher's skill in selecting and organizing learning experiences. It is therefore not very fruitful to try to prove in general that one subject field is better than another. The fact that we who are gathered here today happen to like science and mathematics may be evidence that studying these subjects has been good for us, but it does not follow from this alone that it is wise to require everyone to study them beyond the elementary school.

It certainly seems that some knowledge of these fields is useful to all citizens. It seems to me that we have too often tried to insure this by trying to establish "requirements" and by jockeying among the other subjects for time in the schedule. We act as though we are afraid no one will take our subjects unless we force them to do so. We are acutely aware of statistical data like those showing that in the year 1900 fifty-six per cent of the students in high school were studying algebra, but in 1949 only 27 % were enrolled in algebra. The change for physics was from 19 per cent in 1900 to 5.4% in 1949. These data seem to alarm us, especially when we compare them with the tremendous growth of enrolment in subjects new to the curriculum in modern times. In short, fear that our favorite subjects are "losing out" in a competitive struggle for pupils seems to be exciting some of us.

I believe this fear is largely unjustified at the present time. Moreover, if some concern is justified, we are not in a position to blame the so-called modern methods. On the contrary, we should seriously examine the hypothesis that we are at fault because of unwillingness to modernize the curriculum and to introduce modern methods at a sufficiently rapid pace. If our product is not "selling" fast enough, perhaps it is because we have been too slow in modernizing it.

Before turning to a more detailed discussion of this hypothesis, we should consider a few more facts about the enrolment situation. As teachers of mathematics we are aware that in the calculation of rates in percentage, the base is of some importance. In the relative enrolment figures usually used, the base is the total number of pupils in the last four years of public secondary day schools. It is interesting to study the situation by using as a base the total population ranging from fourteen to seventeen years in age. The resulting per cents give an indication of the extent to which the public schools have made the study of certain subjects available to the *total youth population of appropriate age*. In 1900, only 4.7 % of that population were en-

rolled in algebra. In 1949, the figure had increased to 17%. In 1900, 1.6% of the country's youth were taking physics. In 1949, the figure was 3.4%. Chemistry changed from less than 1% to 4.8% during the same period.

These and similar data make clear in quantitative terms what we already know but too often forget. Today we are trying to teach these subjects to a much larger fraction of the total population than was formerly true. Many of these pupils have little ability and no appetite for intellectual pursuits. The question remains as to whether what we are doing with them is the best we can do. We have, however, become very much more conscious of the wide range in individual differences among pupils at every grade level. The practice of promotion on the basis of age rather than achievement has widened these differences and multiplied our instructional problems. Methods that once worked well now often seem to fail us. Successful teaching is much more difficult today than it used to be, and the use of modern methods is more important than ever before. Let us, therefore, briefly review some general features of these methods.

In the first place, modern teachers put much stress on meaningful learning. These teachers try to make sure that pupils see sense in what they are doing and really understand it. Teachers use a variety of ways of doing this. One popular way is to relate mathematics to situations in which it may be applied—in short, to stress the applications. This works in two directions. On the one hand, we can begin with problem situations familiar to the pupils and help them see the mathematics in them—to develop the new concepts by generalization and abstraction from familiar concrete situations. On the other hand, we can show the pupils situations—practical or even not very practical—new to them but in which familiar mathematical concepts can be applied. In either case, we hope that this process of relating mathematics to real and practical situations will make the concepts more meaningful.

If we examine the trends in the development of materials for children during the half-century just past, we can find clear and convincing evidence of progress toward this kind of meaningfulness. Arithmetic, of course, has always had a strong practical flavor. What we observe is that modern materials rely heavily upon problem situations chosen on the basis of the interests of children rather than those of adults. It is believed that these child-experience situations contribute more to the development of meaning with children than the more adult type of situation once prevalent. At the high school level the trend toward the use of more meaningful experiences is also evident. At this level, however, attention to more adult types of applications of mathematics is common and defensible.

There are, I believe, very few critics who will argue that this aspect of modern methods—that is, concern with the meaningfulness of experience—is not good. If there are some who do argue this way, their views run directly counter to the results of much substantial research by psychologists and others who have studied human learning. It is possible, however, to overdo this attention to the uses of mathematics, or the so-called "social meanings." This is particularly true when social or practical situations are used to introduce new concepts. We must be sure the mathematical aspects are brought clearly into focus and become objects of study. Sometimes this is not done, and although the children may arrive at a solution of a particular problem, they learn so little mathematics from it that they are unable to deal successfully with similar new situations.

A second popular way of helping pupils toward meaningful learning is to use visual or, more broadly, multi-sensory learning aids. The reasons for using these aids are well known to modern teachers, and we do not need to consider them here. The number and variety of such aids now described in the literature has increased much faster than the tendency to be critical about them. It is probably possible to devise a helpful model or aid of some kind to teach any topic you care to mention. Thus, we have aids available for teaching content that is of little or no value. When we examine an ingenious aid, we should ask: Why is it important for the pupil to learn what this aid is designed to teach? We sometimes waste time by skillfully teaching unimportant things.

Although the increased use of visual and mechanical aids is one of the characteristics of modern teaching, in most classrooms this kind of activity accounts for a relatively small part of the instructional time. It is difficult to see how this aspect of modern methodology can be blamed for the alleged deterioration of the schools.

A third and very modern way of helping pupils toward meaningful learning is to encourage them to participate in *planning* the learning experiences. This practice is, of course, in sharp contrast to the usual one in which "the assignment" is made by the teacher. Teacher-pupil planning and similar methods of encouraging interaction among members of the class are still seldom used in mathematics classes. Hence the alleged great deterioration in achievement can hardly be attributed to this as a cause. Similarly, the integration of mathematics with other subjects in a core curriculum is very infrequent. The core curriculum is a focus for attack by some vigorous critics of modern education, but teachers of mathematics are outside this line of fire.

This brief survey of some of the prominent features of modern methodology would be incomplete without some mention of "drill."

It is certainly true that modern methods do not rely on "drill" as much as the older methods did. When learning is meaningful less drill is needed, but plenty of "practice," involving varied work with the same concepts rather than mere repetition, is invariably provided. Sometimes we discover pupils who have not learned what they are supposed to learn. I am sure that this is rarely the result of failure by their teachers to provide practice. Much more often it is the result of failure by the pupil to do the suggested practice because he does not understand the work and is poorly motivated.

In similar fashion and in greater detail we could analyse other aspects of modern methods and the extent to which they are actually used in schools. We would find that the foundation for these methods is well laid in learning theories and research. We would find that these methods are being used more and more by teachers, but that, in mathematics at least, instructional methodology today is nearly everywhere still much the same as it used to be years ago. Critics who assert that the educational process is being ruined by modern methods have greater faith in these methods than most of the teachers do. If the teachers were as "sold" on the modern methods as the critics seem to believe, it would be possible to see much more "modern" teaching in the schools.

Let us now return to one of the criticisms stated earlier. Are we teaching the right things? To this the answer should be "No, not entirely." Most schools are still a very long way from providing adequately for individual differences. For example, they are still trying to teach concepts from algebra and geometry to many pupils who are unequipped motivationally and intellectually to deal with these concepts in satisfying ways. As a consequence, these pupils do not learn very much and understand little of what they do learn. Sometimes they cause disturbances and get into trouble in other ways. You are all well aware of this, but I recall it here because it is another illustration of the fact that our difficulties are more a result of slowness in adjusting to modern conditions than of following the dicta of educational theorists.

Turning to the other and brighter end of the distribution of ability and interest, again we are slow in modernizing the curriculum. Criticisms of the traditional undergraduate curriculum in the colleges have become increasingly common in recent years. These criticisms come not from persons outside the field of mathematics but from those within it. The critics are highly respected mathematicias. They say that the traditional curriculum is barren of the content and point of view of modern mathematics. They say it is high time that courses be brought up to date. Materials for these new courses have been appearing with increasing frequency. To teachers who are wedded to

traditional algebra, trigonometry, and analytic geometry these modernized courses are somewhat of a shock. For many experienced teachers these modern materials require considerable study before it is safe to appear before a class using them.

This same movement is beginning to be felt in the secondary schools. There is growing recognition that a semester of solid geometry as ordinarily taught may not be the best expenditure of time for college-bound students. Similarly, the essentials of trigonometry can be taught in less than a semester. Respectable groups are openly publishing statements that even plane geometry would profit from a somewhat drastic reorganization. In short, there is today more vigorous criticism of the mathematics curriculum than there has been for a long time, and most of it is coming from the mathematicians themselves.

I wonder what Moore, Klein, Hedrick, and other leaders of a generation or more ago would say if they were here today. In their day they were the lonely reformers. They would be fully justified in saying: Why didn't you make many of these changes years ago, before these modern critics came on the scene? In brief, if we choose our leaders carefully and if we avoid obvious opportunities to go to extremes, there is little danger that we will change things at too fast a rate. Valid criticisms will be found to be closely related to slowness in adopting modern content and modern methods. Criticisms that plead for a return to content and method of the past are for the most part invalid. They spring from lack of understanding of modern schools and modern methods and often from emotional rather than rational thinking.

We must recognize that progress can only be made by moving forward. We must maintain and renew our faith in the educational process. Mathematical education today is better than it ever was before, but we must keep on improving it.

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DESIGNING A BASIC SCIENCE COURSE FOR A SPECIFIC COLLEGE SITUATION

W. C. Van Deventer
Western Michigan College of Education, Kalamazoo, Michigan

I. Techniques for the Development of Basic Science Courses

There is no one good basic science course in any particular subject matter field or combination of fields, that is applicable everywhere and under all conditions. Many such courses that are successful have certain elements and factors in common, but none are exactly alike. All must be locally adapted, and the extent to which they are locally adapted is usually a fairly good index of their relative success. We can learn a great deal, however, not only about possible common features, but also about the techniques of local adaptation, by studying what has been done in schools where such courses have succeeded.

When we do this we find that most basic biology courses fall into two general groups, or constitute some combination of these. Both are more or less traditional. They are the "types" courses, in which emphasis is placed on the classification groups of the animal and plant kingdoms, with varying degrees of special emphasis on certain ones, and the "principles" courses, in which the grouping is around factual learnings about the major biological processes. The "types" approach is usually integrated around the idea of evolution, while the "principles" approach usually stresses physiology. In practice, neither approach entirely neglects the other, so that the result is generally some combination of the two, with varying degrees of emphasis on one or the other. Textbooks in the field can usually be classified somewhere on a gradient between a "types" extreme and a "principles" extreme.

General education college science courses, whether they deal with a single field or a combination of fields, likewise tend to fall into certain groups. These are (1) the "survey" courses, which attempt to cover entire areas, even though admittedly superficially, (2) the "problems" courses, which concentrate on certain problems that deal with broad human needs, even though they may approach these on a local basis, through the use of the community as a laboratory, and (3) the "historical" courses, which utilize materials from the history of science to illustrate and teach the application of scientific method and attitude to human problems in general and scientific problems in particular.

A variation of the "problems" approach is the "problem-area"

technique, in which, rather than choosing a series of problems around which to build the course, a series of subject matter areas or topics is chosen, in connection with which problems significant to students and instructor are discovered and developed. Likewise a variation of the "historical" approach is the "case study" method, in which a series of "cases," drawn either from the history of science or from relatively recent scientific work, within the level of understanding of the students, is used as a basis for teaching. Here again, at the actual instructional level, various combinations of these types are possible and are used.

In both "problems" and "historical" courses, with their "problem-area" and "case study" variations, no attempt is made to "cover the field." In this way these types all differ from the "survey" courses, in which coverage of the field, even in cursory fashion, is a prime virtue. Instead these courses use a technique which has been called "block-and-gap." In this, chosen problems, areas or cases are dealt with thoroughly, while others are frankly left out. Unity is given to the course either by grouping the chosen blocks around a common theme or idea, or by giving enough connecting material so that the blocks will fit together and make sense.

The block-and-gap technique is used because it is recognized that coverage of the field is any adequate fashion in a single course is impossible. Proponents of courses which use this technique believe that is it better to do a thorough job with a few topics than to do a superficial job with many. Inherent in the use of this technique also is a belief that an understanding of scientific method and attitude, and an ability to apply it to new problems, is a more important student learning than the accumulation of any particular body of memorized subject matter. The blocks are chosen, therefore, with the idea in mind that they will serve to increase the student's understanding of scientific method and attitude, while at the same time they will give a typical sampling of understandable and meaningful scientific facts and principles. Knowing "how," however, is considered to be more important than knowing "what."

Varying amounts and combinations of laboratory and demonstration work are used with these courses. The ideal of individual laboratory experience, traditional to beginning science courses in both the physical and biological fields, has in many cases been partially or wholly abandoned. Combinations of demonstration work with "group" laboratory experiences, and "finding" or exploratory laboratory techniques, have been widely substituted for it. Serious question has been raised as to whether, from the standpoint of understanding scientific method and attitude, some of the newer techniques may not be actually superior to the traditional individual

laboratory approach, as well as less time-consuming. In many cases, the traditional individual laboratory method has degenerated into little more than a "cook-book" following of detailed directions.

A number of studies have been made in recent years of these new types of science courses in the institutions in which they have been most successful. Among these studies and summaries are those of McGrath (1948), Bullington (1949), Reynolds (1950) and Van Deventer (1946a), (1946b), (1948), (1949), (1951) and (1953). Other studies, particularly those of Martin (1945) and Washton (1952), have dealt with the subject matter principles which are typically included in biology courses for general education.

A new approach to the teaching of basic science courses stems from the work of the Science Committee of the Cooperative Study of the Evaluation of General Education of the American Council on Education, which worked, principally at East Lansing, Michigan, under the chairmanship of Dr. Paul Dressel. This Committee included representatives of sixteen cooperating colleges and universities, all of which had general education science programs in operation. The Committee developed techniques for the utilization of current science material published at the popular and semi-popular level. It was felt that, from the standpoint of teaching, the utilization of such materials, when carefully selected, would bring to the student an abiding interest in the advance of science, and help toward an understanding of scientific method and attitude. From the standpoint of evaluation, the Committee found that such materials would furnish new situations in relation to which the student's understanding of scientific method and attitude could be successfully measured. The work of this group is reported briefly by Mayhew (1952), Dressel and Mayhew (1953) and Van Deventer (1954).

II. Fitting a Course to Student Needs

Basic science courses at the college level, of the type described in the preceding section, are concerned not so much with the presentation of a standardized body of subject matter as with choosing from a subject matter area those principles and materials which meet a particular set of student needs. The first problem, therefore, in designing a basic science course, is to determine the specific needs of the group of students for whom the course is intended.

Some of these needs are, of course, wide-ranging and general, if not universal. Much has been made of the idea that general education must meet universal human needs. Possibly this idea has been overemphasized. If truly universal human needs exist, they may be so elementary as to be meaningless at the college level. Nevertheless a case can be made for some very general needs which apply to the

young people of one generation in one nation, and these must be taken into account in planning any general education course.

Other needs are narrow and local. These have to do with students' geographical and economic origin, pre-vocational and vocational plans, age and sex distribution, and past experience upon which teaching illustrations can be based. These needs and related factors can be summarized by saying that they include (1) what students bring to the course, and (2) what they intend to do with it.

At all points the essentially ephemeral nature of students' life plans at the freshman and sophomore college level must be constantly kept in mind. Women students, with relatively few exceptions, will marry and raise families. All other plans that they may have previously made will be subordinated to this. Men students may start out to follow pre-law or pre-medical curricula, and then eventually become teachers or go into business. Therefore any training which we may give to young people may furnish a foundation for something other than that which was intended, if indeed, it is effective in their later life at all. This is both an indictment and a challenge for whatever general education course planning we do. It means, essentially, that any fact or principle or bit of material that we may choose, is more valuable if it can apply to not one, but two or more specific situations. It means, furthermore, that if in our teaching we can tie our facts and principles, by way of illustration, to homely experiences, such that are common to many or all people of our place and time, we are therefore better teachers, and the things that we present are more likely to be remembered and applied.

The students at Western Michigan College include both men and women. Their age range is fairly wide. Many of them have had one or more years of working experience following high school graduation. Some of the men have had a period of military service. Others, both men and women, have come to college directly from high school. Most of the students are drawn from the local area that the college serves. This includes about twelve counties in the western and southwestern part of the state. Some come from northern Indiana and the urban areas of Chicago and Detroit. A few, particularly among the women taking occupational therapy, are from other states.

Many of the students are Kalamazoo residents who live at home. Many others commute daily or on weekends to their homes in the neighboring communities. The remainder live on or near the campus under typical college conditions. A great many are partially or wholly self-supporting, either working while they attend school, or using money that they have saved while working. Very few of them have had extensive travel experience, or more than a local background.

The group for whom the basic biology course is designed includes,

first of all, those whose major interests lie outside the science area. For these students it must serve a strictly general education function. Most of them will either precede it or follow it with a course of similar length in human geography or physical science, thus fulfilling the general education science requirement for graduation. For most of these, there will be no further college science experience.

Some others who take the course will use it as a foundation for a biology minor for teaching at the secondary level, or as a component of a general science minor for teaching at the elementary level. Still others will use it as a foundation for a required biology block or minor in various specialized fields: home ecomomics, social work, occupational therapy and physical education. In these cases it will normally be followed by one or more additional courses in the biological field. For such students, therefore, it must fulfill not only a general education function, but must also furnish an acceptable foundation for a minimum amount of additional work in the field.

Any general education course must necessarily confine itself within certain definite physical limits. These include the credit block in the total curriculum which can be allotted to it, and the time in actual clock hours that it can be permitted to occupy. The teachers of such courses must constantly fight down the desire to make their courses "all things to all students," by including in them an encyclopedic presentation of the entire subject matter field. To put it another way, general education courses must adjust so that they can "live with" other courses, indeed, with whole curricula. One way in which general education courses must necessarily differ from traditional courses stems from the fact that they have to adjust to a wider range of other courses and curricula than traditional courses have to do.

The basic biology course at Western Michigan College is given for four semester hours credit, during a single semester. It can use up to six clock hours per week. This is divided ideally into three double periods, meeting on alternate days. With an average-length semester, therefore, there is a total of only approximately 90 clock hours available for the course. Whatever goals it has must be accompished within this limit, if at all. The course is called simply "Biological Science." This name is desirable partly because it parallels, in part, a general education course called "Physical Science," from the standpoint of its place in the curriculum. Partly also, it is desirable because it allows wide freedom in selection of subject matter and method of treatment.

III. The Biological Science Course at Western Michigan College

In order to meet the apparent needs of students of the types which

have been described, the Biological Science staff has chosen to develop a course which, insofar as it follows traditional patterns, is a "principles" course rather than a "types" course. Eighty-two percent of the principles listed by Martin (1945), and eighty-four percent of those listed by Washton (1952) are included in the materials of the course. To the extent that it fulfills a general education function, it is a "problem-area," "block-and-gap" course rather than a "survey" course. It utilizes current science materials and present-day problems rather than historical materials and a "case-study" approach. Scientific method and attitude are stressed.

Since the amount of time available for it in the student's program is very limited, the number of problem-areas which it includes must be rigidly selected. Actually, only three are utilized. These are: (I) *Nature, A Dynamic Balance,* (II) *Probability, A Factor in Science and Life,* and (III) *Disease, A Relationship Between Organisms and Within Organisms.* By considering these problem-areas in connection with their natural affinities, it is possible to deal with a fairly wide range of the biological topics and principles which are generally considered important for beginning students.

The entire philosophy of the course is designed to develop an attitude of exploration and questioning. The problems which are taken up are, insofar as possible, real problems. Information is presented not merely because it is information, but because it is an aid, a "tool" for getting answers to questions or solutions to problems. Therefore facts are considered only in relation to functions, whether the subject matter deals with the relationships of living organisms in an aquarium or the passage of food through the human digestive tract.

The balance of nature is chosen as a problem-area because, when it is considered together with its logical ramifications it includes a large number of recognized biological principles. Thus it serves not only a general education function, but also helps to constitute a foundation for advanced study in cases where such is desired. The study of the balance of nature is based on the balanced aquarium and the pond and forest communities. It includes photosynthesis and respiration, the chemical cycles of living nature, food and energy relationships and the structure of living matter. It ramifies into problems of animal and plant taxonomy, cells and cell division, ecology, conservation and evolution. Among the laboratory experiences which are utilized with it are studies of Amoeba, Paramoecium, Euglena, Hydra and the earthworm, and the successional changes in a pond infusion culture. The pond and forest communites are studied by means of field trips in the local area.

Probability is utilized as a problem-area principally because it

furnishes favorable material for the consideration of scientific methodology and scientific attitude, although it also has important ramifications which are purely biological. In connection with achieving an understanding of the scientific learning process, it is important that the student understand the way that a scientist approaches his problems and the kinds of things that he does. Certainly these understandings are no by means limited to a course of this type. The attitudes and methods of science can be learned in connection with studying the material of any scientific field. Every basic science course should include them.

Even though these learnings are not tied to any particular body of subject matter, however, they are rarely learned incidentally. Scientific methods and attitudes, to be specifically learned, must be specifically taught. They must constitute the objective of a unit or section which is designed for the purpose. Such a unit should not be placed at the beginning of a course, because in that case the student does not have enough information to be prepared for it. Neither should it be placed at the end, since there it may be slighted because of shortage of time. It is best placed well into the course, after the student will have acquired enough in the way of general scientific understandings and specific facts to serve as tools for dealing with it, and while the time that can be devoted to it is still adequate. In this course the material on probability includes such a unit, and it is placed near the middle of the course for the reasons stated.

The probability problem-area ramifies into a consideration of molecular movement, diffusion and osmosis, the nature and origin of life, and heredity. Heredity is introduced as illustrative of the general relationship of scientific laws to probability, and also as an example of classical scientific research in a field of intrinsic student interest. Laboratory experiences in connection with this problem-area include the working out of normal-curve and warped probability patterns, hypothesis formation and testing, observation of Brownian movement, osmosis and diffusion, and illustration of Mendelian ratios and multiple factor distribution.

Disease is included as the third problem-area because it makes possible an approach to the study of the human body as a working community of cells, tissues, organs and organ systems, subject to internal and external influences and sometimes invaded by other living organisms in the form of commensals or parasities. Furthermore disease is an area of intrinsic interest and importance to people, both as individuals and as members of society. For many of the students who take it, the Biological Science course constitutes the only contact that they will have in their college experience with a study of the human body. The concept of the body as a working

community is a unique one, and one which students will remember. Furthermore, coming at the close of the course, this concept ties into and reenforces the community concept derived from the study of the balance of nature at the beginning.

Normal body processes and functions are considered along with abnormal states and conditions. Maintenance and coordinating mechanisms are dealt with. Organic diseases are distinguished from parasitic ones, and the relationship of both to heredity and environment is taken up. Mental disorders are included. This problem-area ramifies into a consideration of the development of the embryo, and the parasite-host relationship between mother and unborn child. Laboratory experiences include a dissection of the cat, studies of chick embryos, and a field trip to a hospital for the mentally ill.

Throughout the course the unifying idea is that of interrelationship. This is present in the form of some aspect of the community concept in each of the three problem-areas. We have just pointed out how it is introduced at the beginning of the course under the balance of nature, and again at the end in connection with the human body. It is also brought in under probability in connection with the nature and origin of life. Here the idea is presented that the living cell is essentially a community of chemical compounds, organized under the dominance of self-duplicating proteins, the genes. This is in harmony with the Oparin-Horowitz concept of the evolution of living matter from the non-living.

We have indicated earlier that some such unifying concept or idea furnishes one way of tying together a block-and-gap course. When this method is used, the concept should be one which is not only broad enough to include the units used, but which also reaches beyond them and is meaningful within a broader pattern which the student can use for further integration. The community concept and the idea of interrelationship, which are used here, certainly extend far beyond the bounds of the subject matter to which they are here related.

IV. Teaching the Course

A great many papers have been written describing ideal science courses, with little indication of how they may be carried out. This is typical of the lack of relationship which often exists, especially in the general education field, between educational theory and practice, between stated goals and actual accomplishments. It seems well, therefore, to supplement the foregoing description of the Biological Science course with an indication of how it is presented.

It is obvious that no single textbook which is now available in the field is adequate for a course of this type. It is necessary, therefore,

that the staff look forward to writing a large proportion of their own materials. It may be that some of these will at some future time attain publishable form, in case the course, or something like it, should prove to be exportable. This, however, need not and should not be the primary goal of those who are developing the materials. These are being developed primarily for this course, to meet this need.

Since the development of locally written materials takes time, however, it is necessary that the staff make use of some textual materials as a partway basis for instruction while the work is in progress. For this reason a standard textbook has been chosen, and is purchased by students. Slightly more than half of the material in this textbook is used during the semester. Some of it furnishes a direct foundation for classroom consideration. Other sections of it are used as supplementary reading along with the written material prepared by the staff. Some of the reading in it is specifically designated as "additional" or optional. Furthermore, the order of presentation of the material in the text is rearranged to fit the needs of the course. A mimeographed study guide is placed in the hands of students. This includes outlines of the units, lists of readings from the textbook and supplementary materials, topics for discussion in the form of study questions, and suggested laboratory experiences.

Ultimate use of textbook materials in the course should be in connection with expanded function of library reserves. In this way, sections in selected textbooks which deal particularly well with specific topics would be assigned as outside readings, either optional or required. A sufficient number of library copies of the needed textbooks would be supplied so that this work could be carried out in the time available without undue strain.

Scheduling the course in the form of three double periods each week instead of the traditional lecture-laboratory type of program leaves the instructor free to utilize time for lecture, laboratory, field work or demonstration, or any combination of these, as best fits the material under consideration. This makes for better continuity of presentation, as well as for economy of time.

Laboratory experiences are introduced at all points where they can be made available, and can be used profitably and appropriately. Whenever possible, the entire work of a unit or problem-area is organized around a set of laboratory experiences. The laboratory is literally the "heart" of the course. This laboratory work, however, is not of a "cook-book" type, in which the student is given detailed directions and equally close supervision, and is expected to turn out a stereotyped report. Instead, the laboratory material is presented, wherever possible, in a suggestive fashion, designed to excite thinking, and promote problem-finding and solving. The reports asked for

are designed to allow for wide individual differences in reporting what has been gained. Throughout the work of the laboratory, it is the intention to present chosen aspects of nature as parts of a dynamic complex, in which the answers are not cut-and-dried, and in connection with which real problems can and do arise.

Laboratory experiences make up about one-half of the work of the course. That is, they occupy about one-half of the total class time. Considerable latitude is permitted, however, and individual instructors may use more or fewer experiences of laboratory type. Some of the laboratory experiences which are used follow more or less traditional lines. Others are of the "group participation" type, described by Van Deventer (1953) in which the students in the class are led to recognize and solve problems as a group rather than individually. Even in the more traditional, individual laboratory experiences, such as are afforded by some dissections and microscopic work, the "sharing" of individual experiences among members of the group is encouraged.

Individual instructors are likewise permitted wide latitude in the use of audio-visual materials and demonstrations. This is in line with the administrative concept that the instructor in a course should operate within a broad framework, but should be left free to select and use the materials and methods which he finds most successful within this framework.

In this course it is intended that the student should come to think of science as a process, rather than simply as a body of facts to be learned. It is desirable that he should achieve a feeling of being, at least vicariously, on the "firing line" of the advance of science. He can do this by a careful reading of science-in-the-news. Of course the technical reports of the results of research, which appear in professional scientific journals, are too difficult reading for the ordinary student. Fortunately, however, accurate and acceptable reporting of science news is carried on by such magazines as *Time*, *Newsweek*, *Science Digest* and *Scientific American*. Some daily newspapers also do a good job of reporting science news. These sources are both available and understandable for students.

Students in Biological Science are required to read a minimum amount of science-in-the-news regularly, and to report on it as an integral part of the work of the course. They may choose the topics on which they read within broad limits, not necessarily limiting their reading to topics dealt with in the course, nor even to material specifically in the field of biology. In a great many cases, however, they do seek out and read articles related to what is currently being taken up in class. Sometimes class discussions are initiated through questions

raised by students concerning what they have read in connection with the reports. This is encouraged whenever time permits.

Evaluation is carried on through the use of tests and written reports. The tests used are of objective type, and are used as frequently as is considered necessary by the individual instructor. The subject matter tests are supplemented by the test entitled *Natural Sciences, Form C, A Test of Science Reasoning and Understanding*, worked out by the Science Committee of the Cooperative Study of the Evaluation of General Education, mentioned earlier. This test is designed to measure the student's understanding of scientific method and attitude, particularly as it is related to the reading of science-in-the-news. It may be given both as a pre-test and post-test. When it is used as a pre-test it appears to give a fair indication of ability to succeed in the course. When it is used as a post-test it forms a part of the regular final examination.

A major portion of the student's grade is based on written reports. Students are asked to prepare a written summary of each unit, within each problem-area. Out-of-class field trips and some other special experiences are reported separately. In all of these reports students are asked to organize their thinking on the basis of (1) "What we did," and (2) "What I learned." They are encouraged to stress those points which they feel are really important, and to de-emphasize others, while at the same time giving the unit a complete coverage. Their evaluation of the material earns a better grade, however, insofar as they are able to defend it in a logical and original fashion. Thus the reports are not a uniform, stereotyped product, which simply gives back to the instructor what he has given to the students in as nearly his own words as possible. Instead they are a highly variable, but valuable, picture of the students' thinking in relation to the class experiences.

The dual organization of the reports on the basis of the two categories indicated above helps to achieve the desired result by forcing the student to "break up" his thinking, and reorganize his material. It is not easy, however, to get students to do this. They are accustomed to the process of giving back exactly what has been given to them in the way that it has been given. Furthermore they are conditioned to being evaluated on the basis of the degree of perfection which they can attain in accomplishing this. Original thinking, even in the way of simple reorganization, comes hard. Some students pick up the idea and the skill of carrying it out more quickly than others, and some always do a better job than others, as would be expected. Most of them like the method, however, once they learn it. A thorough explanation by the instructor of exactly what is wanted is

necessary early in the semester, and will have to be repeated individually for those who find it hard to understand.

The readings of science-in-the-news are reported separately and simply, each week as the reading is done. The students are asked to include in these reports the usual data: source, date, title and author (if given) in addition to the summary of the article.

Summary

The development of a basic biology course at Western Michigan College to fulfill general education requirements and at the same time to meet the needs of certain special groups presents a problem which is more or less typical of that presented by the development of other such courses in colleges in this country. It serves to underline the necessity of studying each such situation carefully and adapting the course, as it is developed, to the needs of students in that particular situation. At the same time those working with it must not lose sight of the experience gained in connection with other similar developments elsewhere.

The Biological Science course, as it is being developed at Western Michigan College, is a one-semester "principles" course, of "block-and-gap" type. It includes three major problem-areas: (1) the balance of nature, (2) probability and the nature of science and life, and (3) the body as a community of cells in health and disease. Each of these problem-areas is broken up into a series of units, which include most of the generally accepted biological principles.

A portion of the course utilizes current science news for student reading and evaluation. This serves to give the students a feeling of being at the forefront of scientific advancement, and helps them to know science as a living, growing thing, rather than simply as a body of facts to be learned. Stress is placed throughout the course on learning the methodology and acquiring the attitude of scientists, and applying these to everyday problems. For this purpose a unit in the course is frankly devoted to teaching scientific method and attitude, just as any other subject matter would be taught.

In evaluating student achievement, heavy reliance is placed on written reports, in addition to objective type tests. In these reports students are encouraged to do their own thinking in regard to those portions of the work which they consider most important.

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MICHIGAN COUNCIL OF TEACHERS OF MATHEMATICS

SIXTH ANNUAL CONFERENCE

APRIL 29, 30 AND MAY 1, 1955

The sixth annual conference of the Michigan Council of Teachers of Mathematics will be held at St. Mary's Lake Camp, near Battle Creek, on April 29 and 30 and May 1, 1955. Registration will be held on Friday afternoon, April 29, and the meeting will close with dinner on Sunday, May 1.

The program committee has designated "Continuing Concepts in Mathematical Education" as the theme of the conference. Professor E. H. C. Hildebrandt, formerly both President of the National Council of Teachers of Mathematics and Editor of *The Mathematics Teacher*, will deliver the key address and will serve as consultant throughout the conference. Other speakers at general sessions will be Dr. Lauren G. Woodby of Mt. Pleasant, Michigan and Miss Grace Gish of Kalamazoo. There will be exhibits, mathematical films, demonstrations, and discussion groups prepared or conducted mainly by classroom teachers in Michigan Schools. The group discussions will cover a wide range of interests from arithmetic of the elementary school to the mathematics of the junior college.

In addition to the fine program which is being prepared, the camp affords unusual recreational advantages. This is the best opportunity Michigan affords for its mathematics teachers to get acquainted, exchange ideas, and have a good time together. A cordial invitation is extended to teachers in neighboring states to join with us in this conference. All mathematics teachers, whether in public or private schools, are invited to attend for the full duration of the conference or for as much of it as they can.

The camp is beautifully located on St. Mary's Lake. Meals are served in the main dining hall and there are dormitory-style sleeping accommodations for about 150 persons. Hotel accommodations are available in nearby Battle Creek for those who prefer them. The charge for the conference (including all accommodations at the camp) is modest. Inquiries or requests for reservations may be sent to Miss Irene Smith, Ann Arbor High School, Ann Arbor, Michigan.

EQUATION BALANCES

HOMER C. TORREYSON
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Practically every student of Algebra has at some time been made aware of the similarity of the algebraic equation and the balance. The conventional approach by teacher and textbook is to depict a simple hanging pan balance and show how the left and right members of the equation are like unto the left and right pans of a balance respectively. We then impress upon the student with varying degrees of success the idea that the value of the unknown that causes the members of a given equation to be equal or to "balance" must be maintained through the process of solving the equation.

However, if we attempt to demonstrate the analogy between the equation and the balance we find the simple balance very limited in its application. A naive question by a student such as "How would you solve *this* equation with the balance?" may remain unanswered or be turned aside with the result that the student is not so well sold on the "balance" idea after all.

Many years ago this teacher suggested that a balance system could be constructed whereby all the simple operations in algebra could be demonstrated. We then proceeded to outline the construction of such a machine ending with the remark that "Someday I am going to make such a Rube Goldberg machine."

The machine described in this article is the final result. It was constructed by two students who came to us with a request for ideas for a mathematics project that could be used for public demonstration. Enthusiasm for such a project was heightened by the success of students of Lane in their exhibits at the local Science Fair.

The "equation balances" consists of a linkage of three balance beams, three posts and four hanging pans upon a simple platform. The pans are labeled "right +," "right−," "left +" and "left −." "Right +" and "left −" rise and fall at the same time, as do "left +" and "right −." A pointer attached to the rear beam indicates when the system is in balance.

Hexagonal machine nuts (7/16″) are used as units. Thus 2 nuts represent the number 2, etc. Sets of envelopes are labeled x, y, "empty" etc. Some nuts are cut in halves and thirds in order to demonstrate cases where the unknown contains a fraction. The machine is sensitive enough so that the pointer shows a lack of balance less than a third of a unit. Empty envelopes are provided to counterbalance the weight of the envelopes containing the unknown.

The machine may be used to demonstrate the balance maintained

throughout the solution of an equation of the form:

$$ax+b=cx+d$$

where a, b, c, d and x may be either positive or negative and real and rational. We believe that this offers a sufficient variety of cases to permit the student to "see" exactly how the solution of an algebraic equation maintains a "balance."

Let us illustrate how the machine is used. Consider the solution of the equation: $4x-1=x+8$.

The demonstrator will need several envelopes each marked x and containing 3 nuts and some empty ones.

Solution (*a*)		*Solution* (*b*)	
(1)	$4x-1=x+8$	(1)	$4x-1=x+8$
(2)	$4x-1+1=x+8+1$	(2)	$4x-x=8+1$
(3)	$4x=x+9$	(3)	$3x=9$
(4)	$4x-x=x-x+9$	(4)	$x=3$
(5)	$3x=9$		
(6)	$x=3$		

In solution (a) the axiom method is used, while in solution (b) we transpose.

Solution (*a*)

	Left +	Left −	Right +	Right −
(1)	$4x$	1	x, 8 ,3e	
(2)	$4x$, 1	1	x, 8, 1, 3e	
(3)	$4x$		x, 9, 3e	
(4)	$4x$	x	x, 9, 3e	x
(5)	$3x$		9, 3e	
(6)	x		3, e	

Solution (*b*)

(1)	$4x$	1	x, 8, 3e
(2)	$4x$	x	8, 1, 3e
(3)	$3x$		9, 3e
(4)	x		3, e

Thus through the successive steps we may witness that balance is maintained. It may also be shown that an error or an illegitimate

operation disturbs the balance. We may emphasize any particular feature of the solution that we wish. Thus in solution (a) in going from (4) to (5) we combine a positive and a negative quantity of the same absolute value on the same side to give zero.

The versatility of the machine may be demonstrated by the solution of the following set:

$$\begin{array}{ll} (1)\ \left\{\begin{array}{l}3x+2y=11\\ 2x-3y=3\end{array}\right. & (6)\quad x=3 \\ (3)\ \left\{\begin{array}{l}9x+6y=33\\ 4x-6y=6\end{array}\right. & (7)\quad 9+2y=11 \\ (5)\quad 13x=39 & (8)\quad 2y=2 \\ & (9)\quad y=1 \end{array}$$

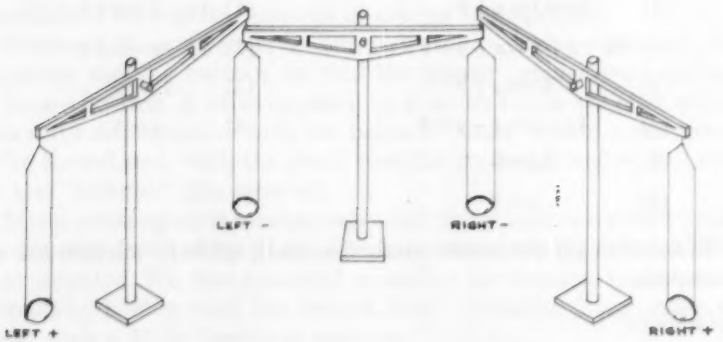

FIG. 1. Three beam balances form the "equation balance."

Here we first set up equation (1) then (3) which may be removed from the pans temporarily while (2) and (4) are set up. The rest follow in order.

Similarly we may demonstrate solutions in which a, b, c, and (or) d may be fractions (mixed) or literal numbers. Equations containing simple parentheses may also be illustrated.

Questions such as "How may we demonstrate the solution of equations having a negative value of the unknown?" may arise. One answer is "If we had a substance which has a negative reaction to the pull of gravity, we could do it." Balloons filled with hydrogen could be used but such a demonstration would scarcely be worth the effort. Obviously the chief difficulty here is to set up the original equation and achieve a balance. This may be overcome by marking our envelopes as $-x$ instead of x.

Example

$$(1)\qquad 5x-2=9x+6$$

$$(2) \qquad -5(-x)-2=-9(-x)+6$$

$$(3) \quad -5(-x)+9(-x)=+6+2$$

$$(4) \qquad 4(-x)=8$$

$$(5) \qquad (-x)=2$$

$$\text{Or} \qquad x=-2$$

We may demonstrate the solution of equations whose unknown may contain a literal number by providing nuts of other sizes to represent such literal quantities.

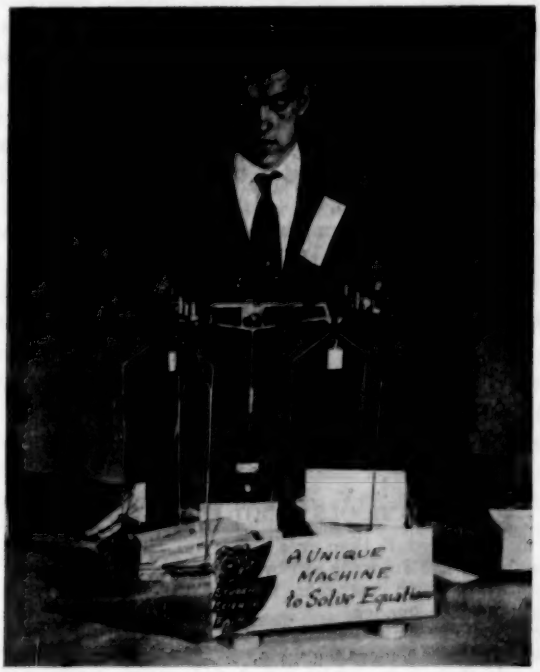

FIG. 2. The equation balance demonstrates the solution.

We may also demonstrate that the product of two negative numbers is a positive number. In this we utilize the concept that the removal of a quantity from the balances is a negative operation. We show that when we remove a number of negative quantities from the balances and add the same number of positive quantities the system is in the same state of balance.

For example to demonstrate:

$$(-3)(-4)=+12$$

we place twelve nuts on the "left +" pan and add the same number on the "left −" pan. The system balances. We then remove four nuts from the "left −" pan, remove four more, and remove the last four. The system is unbalanced. We place these twelve nuts on the "right +" pan and balance is restored. Thus three removals of −4 is equal to 12 or

$$(-3)(-4)=12.$$

The machine was constructed by two juniors at Lane Technical High School, Arthur Schultz and Curtis White, and demonstrated by them at the meeting of the Central Association of Science and Mathematics Teachers at the Edgewater Beach Hotel in Chicago on November 28, 1952. The work was done in the physics laboratory.

The equation balances at Lane is available to any teacher on the staff who requests its use. Students are trained to demonstrate it, and are responsible for keeping it in working condition and returning it to the storeroom.

We suggest that a similar machine may be constructed by teachers in other schools. We believe that it definitely assists the student in bridging the gap between a mechanical world and the abstract study of Algebra, but like any other visual aid should be used as an accessory only.

Its use should not overshadow the learning of the fundamental algebraic processes, nor should it ever be considered as an "electronic calculator," nor in any sense a substitute for work.

OUR SCHOOLS NEED MORE MONEY

We have more youngsters than ever before
Fewer youngsters are dropping out of high school
Today, educating youth costs more money
—Classes must be smaller
—Effective teachers use modern tools of instruction—motion pictures, supplementary books, magazines, etc.
—Your schooling may not have included courses in music, art, physical education, home economics—but your youngsters have and need them
—Specialization has entered the schools, too—today, your child is helped by psychologists, career guidance counselors, school nurses, and other types of specialists

—From The National Association of Manufacturers

New 35 mm. film for "candid" camera fans has a super-thin, fine-grained, black-and-white emulsion to yield greater detail. Available in three degrees of sensitivity from "slow" to "medium fast," the slowest film can resolve 140 lines per millimeter, and the fastest, 90 lines.

THINKING MACHINES AND YOUR TELEPHONE*

HOWARD BAMMAN
Illinois Bell Telephone Co., Chicago, Ill.

I want to show you and demonstrate for you some pretty intriguing electro-mechanical machines . . . machines that can remember and play games. And we have some interesting ideas about what your telephone service is going to be like in the future.

But before I get to these, I want to show you what I think is the most useless object you can think of. It's this.

Now, you think I'm crazy . . . a telephone man saying a telephone is useless. But this isn't actually a telephone, for there are no wires connected to it. It's just a telephone instrument, and not being connected to other telephones, it doesn't do a thing but just sit there. It doesn't make a very good hammer, even though sometimes it's used as one. You can spin the dial on it, but all that does is make a little sound . . . nothing else. If you turn it over, the receiver falls off . . . and this wire gets caught in things if you carry it around. It isn't even a good paper weight . . . too heavy and too big for that. I think you'll agree, it's about the most useless object you could have around the house.

But what happens when we connect a pair of wires to it and run them to the nearest telephone exchange and connect them to the equipment there? Why, it becomes about the most useful object around your house. Because with it you can talk to people at 52 million other telephones all over the country . . . some 84 million throughout the world. And you can do it in a matter of seconds. But you already know all this . . . you use the telephone every day. What you might *not* realize is the immense job of selection required to let you pick one telephone out of thousands or millions . . . just like that.

Now, it's a simple job to pick just one specific ping-pong ball out of a bowl-full. There's one red one in here somewhere, mixed up with all these white ones. All we have to do to select it is wave a hand over it . . . and presto!

But you can't just wave your hand at a specific telephone and have it ring.

Well, what do you know? Apparently *I* can!

But, seriously, the problem with a telephone system is making it possible for any one telephone to be connected to any other of the telephones, quickly and conveniently. Let's take a minute to see how complex that can get.

* A Demonstration presented at the noon luncheon meeting of the Central Association of Science and Mathematics Teachers at Chicago, Friday, November 26, 1954.

Now, this is that single telephone which is useless unless it can be connected to other telephones. So, we introduce a second telephone, and connect the two with a pair of wires. Now they can talk to each other over these wires. When a third telephone is added, we must add another pair of wires. But one extra pair won't do the job, will it? So that all these phones can reach each other, we'll have to put in a pair of wires here, too. With four telephones? Three more pairs of wires. When we put in the fifth telephone, we must add *four* pairs of wires. And, the sixth telephone requires an added *five* pairs of wires.

Well, I think you're beginning to see the point. The number of wires increases *faster* than the number of telephones. With six telephones, we need 15 pairs of wires to interconnect them. If we kept on adding telephones, the wire situation would get desperate.

We have a formula we can use to find how many pairs of wires are needed to connect a given number of telephones. T times T-minus one, divided by two. If we apply that formula to our six-telephone system here, we take 6, the number of telephones, times 6-minus-1, which is 5, and that gives us 30 doesn't it? And 30 divided by 2 is 15. Fifteen *pairs* of wires to connect just 6 telephones. And that's what we have here.

With a hundred telephones we need . . . let's see . . . 100 times 99 gives us 9,900 . . . divided by two . . . 4,950 pairs of wires required for 100 telephones. Now, many of our telephone exchanges have as many as 10,000 telephones in them. We would need almost 50 million pairs of wires to connect all the telephones to each other.

Well, obviously, we don't in actuality have 50 million pairs of wires running between the phones in an exchange. Soon after the telephone was invented, it was seen that such an arrangement was impractical. The cost of such a vast system of outside wires would be prohibitive, and it would be nearly impossible to maintain it. Early in the game, it was obvious that some sort of central switching system would have to be devised.

So, "early in the game," they devised one. The early telephone men came up with a switchboard, and they located it in the central office.

That made all these extra wires unnecessary. All that was needed was a pair of wires from each telephone to the switchboard. Even though this move got rid of a complex system of outside wires, it did not get rid of the complexity inherent in a telephone system. The complexity is just transferred from the outside wire system into the central office. Nor did it eliminate the cost factor. It was no longer prohibitive, but the long rows of equipment and the miles of indoor wire represented a huge expenditure. The same is true today. We still have to provide a means for connecting one telephone to any one of

the others in the system. And remember, the number of interconnections increases faster than the number of telephones.

Well, the telephone switchboard provided a means to make these interconnections. Now, you all know what a switchboard is . . . don't you? Well, basically it's a simple mechanism. I can demonstrate it with this board, and this piece of string. Let's say each of these holes represents the end of a pair of wires. They terminate here, and on the other end is somebody's telephone. Let's say Jones is calling Smith. Now, here is Jones' line and here is Smith's. All the operator needs to do is connect Jones' line to Smith's with this little length of telephone lines, and they can talk. Of course, she can connect any two of the telephones represented here.

Essentially, that's a switchboard. Of course modern switchboards are a great deal more complicated than that, but, essentially they are the same as the boards that did the job in Alexander Graham Bell's day. It's a perfectly good system except that it's not adequate for many of the huge metropolitan systems we have today.

The number of operators and the amount of space needed for their switchboards would be far too expensive. It would put the cost of telephone service out of reach to all but the wealthy.

So, the need for an automatic switching system showed itself many years ago. And today, the bulk of the telephones in this country are switched automatically . . . by what we know as the dial system. And the program of converting all phones to dial is going ahead at full speed.

Now, I could spend hours talking about all the things an automatic telephone system can do, but I'm not going to. It's sufficient to point out that they can perform the nearest thing we know to some of the human thought processes. These machines almost seem to "think." They receive numbers, remember them, identify the calling subscriber, have stored up in their electromechanical brains several routes for reaching the called number and can sense in a split second which route is free. We will see such a machine a little later on.

Built into much of this automatic telephone equipment is an automatic trouble shooter. When the machine develops trouble, the trouble reports itself—its nature and its whereabouts—by lights or cards. It can't make a mistake. If it gets sick for some reason, it refuses to go to work at all—it just notifies its human attendant just what is wrong and waits till he's fixed things.

I might summarize the telephone switching story by reminding you that when you pick up your telephone and dial a number you are really assuming command of the most complex mechanisms man has ever known.

Complex it is, but the heart of these complicated giants is a rather

simple little mechanism which makes modern day telephony possible. Here it is . . . it's a special type of electric switch . . . called a "relay."

Some of you probably know what a relay is. There are relays in your automobile . . . and in a great many other machines and appliances you come into contact with every day. This is a telephone relay, different in some respects, but basically like all other relays. It's a simple mechanism, really, but used in combinations, these little giants can do the most stupendous things. In your telephone system they accept information, analyze it, remember it and take appropriate action on it. In this machine they play the old school-boy favorite, tic-tac-toe. We'll see them do that in just a minute. But first, for those of you who don't know what a relay is, let's take a minute to build one.

The principle of the relay is that of magnetism. You've all seen magnets. Maybe you've seen the kind the relay uses . . . an electromagnet.

I have an electromagnet here, made up of an iron rod core, in this case shaped like a horseshoe, around which there are many coils of copper wire. This wire is attached to this battery, and when the current flows through these coils, it sets up a strong field of magnetism. Then, when I turn off this switch, the current stops and the magnet doesn't operate.

Let's try it.

Well, that principle of electromagnetism is what makes a relay work.

Let's go over here to a model relay. Most models are smaller than the real thing . . . this one is larger . . . so that you can see just what a relay does. Here is our electromagnet. When we push this button, the magnet moves this arm to close these contacts which in turn rings a chime. Actually a telephone relay is made up of several arms or fingers of this type. Now, let's try it.

That is the kind of chime many folks are having installed in place of their regular telephone bell these days.

Now, we can do other things with this same relay, too.

That's the bell we install for folks who are sound sleepers.

Or, we can do this with the relay.

That might very well be the light on your telephone operator's switchboard. And when you call her, it's a relay which actually does light her light.

This next demonstration will show you some slightly more complicated maneuvers of relays which are essential to a modern telephone switching system.

Here we have four telephone relays, each one made up of several arms or fingers such as we just saw. These four, wired in combination, can add and subtract, among other things. The top one here repre-

sents "one." When we throw the switch, it registers the number one on this panel over here. The second relay represents "two." And the same for "four" and "eight." Let's add them up. One, two, four and eight should make a sum of 15, shouldn't they. Let's see if they do. One and two make three. Right. Add four to make seven. Right so far. Add eight, and we have fifteen.

Let's try subtracting four from the fifteen. Eleven. Subtract two . . . nine. Take away eight, and it leaves one.

By adding just one more relay to this combination, we can make ourselves a combination lock. And we can use it to lock our refrigerator here, in which hangs a most precious piece of beefsteak. Let's make 4 the combination which will unlock the refrigerator. Now then, only when we turn on the number four relay will the lock open the door. When we try 2 or 1 or 8, all we do is set off the burglar alarm. Only 4 opens the door.

Now, of course, if we did have a burglar, or more likely my hungry brother-in-law, it wouldn't take him long to find our combination through trial and error, and if the alarm didn't wake us up, he wouldn't have any trouble getting away with our steak.

But we can put a stop to that by adding one more relay to our system . . . a remembering relay.

Now, we can set up a two-digit combination which I don't think even my brother-in-law can find accidentally. Let's make our other digit . . . 8. Now, the 4 won't open the door by itself. But, when we precede the four with the 8 . . . the door opens because this relay remembers the eight has to be in there. And, in this position, the 4 will open the door each time, as before. But, before we go to bed at night, we tell the rememberer to forget that the four will open the door. It will open it one more time . . . then it forgets. And now, to open the door, we have to play first the 8, then the 4, each time. So, with just six relays we can make this machine remember. Now, I realize I went pretty fast through that, and you may not have caught it. But I think as we go along it will become clearer.

Well, if six telephone relays can receive the combination to our refrigerator, analyze it, remember it and take appropriate action . . . what do you suppose 50 relays can do?

For one thing, they can provide us with an electronic tic-tac-toe board. What say we give it a try.

Now, I'm going to ask one of you to play a game with me here, but first I'd better explain how we play it. Instead of a piece of chalk and a blackboard, we have telephone dials and our automatic board here. If I want to make my mark in the upper left-hand corner . . . the corner numbered one . . . I dial one on this dial.

If my opponent wants to put his mark right in the center square,

he dials five. To clear the board, we just dial "operator." And the machine will let us know who won.

By the way, you can see this machine think while it plays the game. You may have noticed these lights going on and off during the game. Each one of these lights is connected to its relay just below it, and the light goes on when that relay is operated. You can actually see it accept the information you dial it, remember it, analyze it and take appropriate action.

Let's try it once, and you watch the lights.

You can see this light blinking as the machine accepts the information you sent it . . . in this case, the number you dialed. Then it puts up your mark, and with this relay, remembers where you put your mark. Then, before it plays, the machine analyzes the situation . . . takes a look at how the game is going. Then, it takes appropriate action . . . makes its mark in just the right square. At the same time, the machine takes a look down here after each move to see if anyone has won the game yet.

You know, I wish some of you folks back in the back there could play, but I'm afraid our cords wouldn't reach. May be we can use one of these useless telephones I have here. See, no wires. The other one rang a while ago—let's see if *this* one can help us out now.

Let's give it a try. Well, what do you know—that telephone has some use after all.

Well, don't feel bad folks. Nobody anywhere has beaten this machine yet. Even my brother-in-law couldn't beat it. It's impossible.

By the same token, this type of equipment in a telephone office is rigged so it can't be beat. It will give you the number you dialed every time. And just like the relays in this machine, the equipment in the telephone office accepts the information you dial, remembers it, analyzes the situation to see if the line is busy and so forth, then takes the appropriate action of connecting you and ringing the phone or giving you a busy signal, or whatever action is appropriate.

I'm sorry we don't have time to let everyone have a crack at this . . . maybe after the show we can get some competition going.

Fifty relays do everything required to play this game . . . and play it well. They accept information, remember it, analyze it and take appropriate action on it. With 125 relays, we can do something a little more complicated.

We can make a mechanical brain for our little electrical mouse here. And he's going to need one because we're going to start him out in this maze and see if he can find this piece of cheese. And once he's found it, he will have to remember just where it is so he can go

straight to it on the second try. Okay, Melvin, (that's the mouse's name) see if you can find the cheese.

Well, that wasn't so bad now was it, Melvin. Now, I'll bring you back home here and start you out again.

Now, are you sure you know how you found the cheese last time? Okay . . . just remember, no fumbling around . . . you go straight to the cheese.

Very good, Melvin! Remind me to give you a nice piece of real cheese after the show. Now, just to show you that Melvin is versatile, I want someone to come up from the audience and move the cheese to any place on the board and we'll see how long it takes Melvin to find it.

Now, just to prove that there's no trickery involved in Melvin finding this cheese, I'll put a *blindfold* on him!

That's not too tight, is it Melvin? Okay, straight to the cheese now.

Well, this is just another illustration of how telephone relays can accept information, remember it, analyze it and take appropriate action on it. They can be so arranged as to find a path to a finish line and then remember what that path is and keep it open.

In a similar way, the relays in your telephone central office find a path for your telephone call, remember it and keep it open while you talk. Of course they find that path in a second or two. Melvin takes a little longer. Now there are quite a number of possible routes Melvin can travel up here and remember . . . but they aren't nearly so numerous as the number of routes or paths your telephone call might take. Here in Chicago, you can call any one of some 1,622,000 telephones. In order to handle this big order, there are no less than 175,000 relays like these in a central office. And you operate as many as 1,700 of them every time you make a local call.

These entertaining machines we have seen here today are a sort of by-product of the extensive research in telephone switching systems that is constantly going on at the Bell Telephone Laboratories. The end product of this research is much more practical, you may be assured. We're in the telephone business . . . not the tic-tac-toe business.

And being in the telephone business . . . we are constantly confronted with the complex problem of switching which we saw illustrated earlier. This problem has become quite stupendous in the past few years as telephone men have started to build a nationwide automatic system . . . a system which will one day allow you to dial your own long distance calls . . . to any other telephone in the nation just as you dial your local calls today. Remember how complex the switch-

ing problem became with 10,000 telephones? Nearly 50 million possible interconnections had to be provided for. Imagine how many interconnections must be foreseen and provided for in a nationwide system involving 50 million *telephones*! Simply stated, the problem is that of finding a path for a call from let's say Chicago to San Francisco and then singling out the one telephone in San Francisco being called . . . and doing it automatically.

That is actually being done today in several communities around the country, and more and more customers are receiving this special service every day, including some in Illinois.

Long distance operators across the country are today dialing more than half of all long distance calls direct to the telephone being called in the distant city . . . without going through a second operator.

One machine that is vital to the success of this system is the machine we call the card translator. That's the machine that will automatically pick out the path for your long distance call, and this is a model which can demonstrate how this machine operates.

Let's set up a theoretical call between Chicago and San Francisco. All the Chicago customer would have to do to get to San Francisco is pick up his phone and dial . . . and there's his path, straight to the coast. Simple, isn't it. Once he's there, he can then dial the number of the phone he wants to reach, just as if he were in San Francisco.

How did he get there? He dialed three digits . . . 4–1–5. That is the code that has been assigned to San Francisco area for long distance dialing purposes. It's part of a nationwide plan which, when complete, will give every telephone in the United States and Canada a distinctive number, not duplicated anywhere in either country. The first step in this plan was to divide the United States and Canada into some 90 areas, each with an identifying three-digit code. Each telephone exchange in an area will have a distinctive three-digit code, two letters and a number, which isn't duplicated anywhere in that area. And, of course, each telephone in an exchange already has a distinctive number.

Therefore, a 10-digit number, the area code, the exchange code and the telephone number, will single out one particular telephone from among the 55 million in the United States and Canada. The first three digits of that code are the area code numbers. San Francisco's is 4–1–5. And that's what we dialed to get there.

New York's area code is 2–1–2 . . . so to get there, we dial 212 . . . and there's our path to the East Coast.

Now, when the Chicago customer does this, it's just possible that this straight path of lines to San Francisco may be busy. What then? Well, there are other ways to get to the coast, and this machine knows just what those ways are . . . no matter how complicated.

Now, our straight path is busy. Let's place another call to San Francisco and see if we get through.

There we are. It didn't take any longer . . . though the call travels farther. The switching equipment found that the first path was busy, so it immediately searched for a second path to use using the information the card translator provided. Just like our mouse and cheese, remember? We have alternate routes to New York, too. This one's busy, so let's put through another call to New York and see what happens.

This machine, to a great extent, does the work of a long distance operator. It determines where you are calling and finds a route to send your call over.

And here is how.

In the card translator, you will find a row of cards, standing on edge . . . like these. These cards have holes punched in them . . . something like this . . . holes punched in just the right places. Notice some of the holes are larger than the others. Each of these cards . . . has a different pattern of enlarged holes, and each one represents a bit of information needed to route the call. Behind the row of cards, there is a light bulb . . . beaming its light to the cards. In front of the cards are situated a number of accurately placed phototransistors . . . similar in their operation to photo-electric cells . . . or electric eyes.

Begin to get the idea? The light from this bulb shines through the holes in the cards and activates these phototransistors.

In effect, the phototransistors read the information on the cards and pass it on to the switching equipment.

I'll hold up two cards here, each with holes in them. When I hold them together like this, the light passes through, and you can see all of the holes. But when I shift one card down just a little, you see light pattern change. And that's just how it would be if you were the phototransistors, these were the cards, and the light from the stage here was our light source in the machine.

When the machine is not in operation . . . the light shines through all of the holes because the holes are in line to let it pass. When we dial our code, one of these cards drops down just a fraction of an inch. Did you see it? Probably not, but this little green light went on momentarily . . . and that showed which card dropped down.

Let's take it slowly this time, and you watch for it . . . there we've dialed our code, then the card drops down and this light goes on to show that it's down. Now, when that card drops down, it changes the position of some of its holes changing the pattern of light passing through to our phototransistors directly behind. The phototransistors read the information on the card and pass it on to the equipment

which switches our call to New York. Then, on the second step, the route is selected, and the card pops back up again. Now, of course, any one of these cards can drop down, or several at one time . . . depending on what code is dialed. When we dial the San Francisco code, the machine knows which card to drop down which in turn activates certain of phototransistors here. The card relays not only the destination information but also alternate routing information. Therefore, from the signals put out by the translator, the related switching equipment knows just what routes to try if the first route is busy.

That's an awful lot of information for one machine to produce and do it in a matter of seconds. But you begin to get an idea of how complex this machine is when you realize that one call might take any one of some 800 different routes to its destination. Where our model here shows only ten cards . . . the real thing holds more than a thousand. Where we have three phototransistors here in the receiving end . . . the real thing has over a hundred.

Well, you might ask now . . . "what ever happened to our old friend the relay?" Our signal from the card translator passes to relays which do the actual switching of our call on the way to its destination.

Relays are also utilized in the operation of the card translator itself. I think we can safely say that this complicated machine would be useless without the help of our simple old workhorse, the relay.

You may well ask, what effect has the mechanization in your telephone system on employment? I still find a few people who will argue that mechanization tends to destroy jobs. Actually, the fact is quite the opposite.

In the Bell System alone, there were 275,000 employees when the first Bell System dial telephone was installed. Last year (1953) when 81% of all Bell System telephones were dial operated, the number of employees had grown to more than 700,000. The natural demand for service, stimulated by the better service we could provide, has increased much faster than the phases of the job being done by machine. The machine, then, has actually created jobs.

You know, when you see such machines as these operate . . . doing their amazing automatic tricks, you're tempted to say they're almost human.

Well, they may be more nearly human than you think. Recently a group of scientists studying the function of the brain suggested that it works in a manner quite similar to these machines here on the stage. The relays that do the brain work here operate on what is called the "yes-no" characteristic. An electric signal is either on or off—a circuit is either open or closed—the relay is either operated or released. That's the "yes-no" characteristic. These brain scientists are now speculating that the tiny neurons in our brain work the same

as relays—with the "yes-no" characteristic. They say that a decision is either yes or no—a situation is this or that—or this but not that—or this and that—and so on.

They draw another parallel. Where our telephone relays are connected by wires—brain cells are connected by nerve fibers.

Nature is not to be outdone, however. The brain contains 10 billion neurons and is only about this big. It thinks profound thoughts (some of them do, anyway) such as the theories of Einstein.

Our switching machines contain only a few thousand relays—they require whole buildings to house them—and all they can do is accept information, analyze it, remember it, and take action on it.

So, we still aren't in the same class with the brain.

You've seen the "latest thing" in telephone switching here, but in the minds of some of our Bell Labs engineers—it's already obsolete. They are never satisfied—always looking for a better way. At the present, they are experimenting with electronic switching mechanisms which operate on an entirely different principle from these. If they prove to do a better job—at less cost, then eventually they will replace present-day equipment—which will help carry forward the Bell System aim of providing you with the best possible telephone service at the lowest possible cost.

SCHOOL NEWS FROM THE NATIONAL ASSOCIATION OF MANUFACTURERS

The National Association of Manufacturers reported today that educational facilities are not keeping pace with the growth in population or with the rise in national income. Serious shortages of teachers and classrooms exist and "the situation is getting worse," the NAM said.

"Our schools need more money—what they get isn't enough," the association declared. "We are spending proportionately less of our income on schools today than we did in 1930 and even then the schools were inadequately supported."

Reporting on a study of the public schools, the NAM said that the number of children entering schools is continuing to rise at a rapid rate, too few teachers are being trained, school construction is lagging behind needs, and tax support is not increasing at a sufficiently rapid rate.

The study, made by a committee of educators and industrialists who worked with the NAM's Education Department, showed that the public schools face even greater influxes of new pupils in the years ahead than in the years since the war.

Enrollments in public elementary schools rose by less than 4½ million in the past eight years, the report noted. But in the next two years, it pointed out, a 2,400,000 increase is expected and by 1958 the total may reach 26 million, or 4 million above the number now in school.

One of the most serious aspects of the school situation, the report explained, is the critical shortage of teachers. This is now felt mainly in the elementary schools, but is certain to affect high schools and even colleges.

Teachers' salaries must be raised in order to encourage more young people to enter the teaching profession and remain in it, the committee concluded. The average salary of public school teachers last year, it said, was only $3,605. And 29 states paid salaries below this national average. Many rural school teachers receive as little as $1,700 to $2,000, the report noted.

ABOUT THE SCIENTIFIC METHOD

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Articles and references relating to the scientific method are numerous, but there is a disparity as to how to define it. There are those who say that there are many scientific methods and that there is no satisfactory definition possible (1). It is defined by them as a set of operations used in finding a solution to a problem which arises out of several actual experiences. P. H. Bridgman states it thus (2): "The scientific method, as far as it is a method, is nothing more than doing one's damnedest with one's mind, no holds barred." This inability to define specifically the scientific method apparently rests in being unable to define the basic principles. But since basic principles must and do exist, they should be capable of being stated.

Those who define the scientific method describe it as a systematic or organized process to obtain useful knowledge by observing certain principles, which principles they then proceed to state (3). Some authors state these principles, as does W. F. Ehert, in this sequence: observation of facts; arrival at a hypothesis which agrees with the observation made; elevation of the hypothesis to the state of a theory; and the designation of the theory as a law if it stands the test of time (4). Somewhat contrary to this sequence are the steps as stated by other scientists. The first step, they assert, is the accumulation of experimental data. From the correlated data generalizations are developed which are summarized in a statement called a scientific law. After a law has been established the question as to why it is true arises, and what is the explanation for the behavior it sets forth. A plausible explanation is a guess or a hypothesis which can become a theory (5).

In the examination of about sixty-five inorganic and general chemistry textbooks for colleges on their reference to the scientific method, it was discovered that about ten authors used the first sequence of steps while fifteen others gave the latter sequence to explain the scientific method. It is of interest to remark that about fifty did not even mention the scientific method or refer to it. This fact causes one to wonder whether it is receiving sufficient attention in the field of scientific education.

But to return to the discrepancy noticed in the sequence of steps. Much of this is due to the use and meaning of the words law and theory. A law is a statement of a general and constant mode of behavior, which has been shown to be true from studying the facts pertaining to some happening. It gives science its foundation. A theory

differs from a law in that it uses ideas which are not capable directly of experimental proof. No theory has ever been proven. A theory can be defined as a structure of correlations to coordinate and interpret natural laws (5, 6). A theory should lead the way to further research. Since it need not be a permanent thing in itself, it may be modified or discarded as new facts are discovered. Each new law further tests a theory.

When certain authors state that a theory can become a law, it would appear that they are referring to a hypothesis which has been more firmly tested. A hypothesis is a trial idea or guess which could become *either* a theory *or* a law. If as a result of observations and experiments, a trial idea concerning the nature and connections of the observations is developed, a hypothesis results. This, when further tested and substantiated, becomes a law (7). If, on the other hand, one attempts to explain the reasons why a law is true and why certain causes lead to certain effects, again a hypothesis is formulated. However, when such a hypothesis has stood the test of many experiments designed to check it, it becomes a theory (8).

It seems that those authors who define the scientific method as experiment, hypothesis, theory, and law give an erroneous interpretation of the word theory. This sequence of steps might be indicated better as experiment, hypothesis and law, since the term theory so used is only a more certain step in the classification of the fact as a law. If they insist in naming the step before a law a theory, theory so used is just a bit more convincing than hypothesis, because in their case both the theory and hypothesis indicate a trial idea which may become a law. However, in actual practice, after laws have been established, the application of these laws develops into a theory, that is, a structure built from the coordination of laws.

In my mind the best way to explain the scientific method to students is to define it as an organized process, at times extremely complex, but usually following this general pattern of procedure: collection of the data relating to some problem; formulation of a law as a result of the classification of the facts; and the statement of a theory which is an explanation and interpretation of laws.

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OSBORN AWARDED FELLOWSHIP AT WISCONSIN

The opportunity for study in the history of pharmacy, medicine, science, and related social studies at the University of Wisconsin has brought Dr. George E. Osborne, associate professor of pharmacy at the University of Utah, to the Madison campus for the 1954–55 academic year.

Dr. Osborne has been awarded a faculty fellowship by the Fund for the Advancement of Education, a subsidiary of the Ford Foundation. This fellowship is apparently the first of its kind awarded in the field of pharmacy by the Ford Foundation, according to Dr. Arthur H. Uhl, dean of the University of Wisconsin School of Pharmacy. The Foundation expects to make better teachers of those already in the teaching field by encouraging study of related areas, historical backgrounds of a professor's field of specialization, and various methods of presenting instructional material, he explained.

"We are pleased that our department of the history of pharmacy, together with the University's history of science group, can offer an opportunity for this educational experiment," Dean Uhl said. "Dr. Osborne is one of the young professors of pharmacy whose broad outlook and historical interests promise a fruitful blend of scientific and social knowledge in the teaching of pharmacy students. From that comes, I believe, a better-educated, professionally-responsible graduate. The Ford Foundation is to be congratulated for extending its faculty fellowships to the field of pharmacy."

A native Hoosier, Dr. Osborne received his undergraduate and graduate training at Purdue University. He is a veteran of the World War II Navy, having served with the rank of lieutenant, senior grade. His teaching experience includes posts on the pharmacy faculties of the University of Kansas, Purdue, and the University of Utah. He is a member of a number of honor societies and professional groups including Sigma Xi, Rho Chi, Kappa Psi, the American Institute of the History of Pharmacy, and the American Pharmaceutical Association. During the past year, he served as secretary for the section on historical pharmacy of the Association and was elected this year to the vice chairmanship of the section.

"LIVING FOSSIL" INSECTS IN DEATH VALLEY POND

Two populations of rare insects, so-called "living fossils" from the Ice Age, have been discovered in Death Valley.

The discovery was made in a pond near Saratoga Springs, by Dr. John Belkin and William McDonald of the department of entomology at the University of California at Los Angeles.

One group of insects is evolutionally midway between gnats and true mosquitoes, and is known as Corethrella laneana. This species has also been identified in Mexico. However, the Death Valley species is different enough to suggest a distinct subspecies.

The other "living fossil" is a true mosquito. Known as Uranotaena anhydor, it is related to a type found in Texas. It is thought to feed on frogs.

Both populations of insects apparently have been isolated in the desert area since the end of the last glacial period.

In the same area Dr. Carl Hubbs of the Scripps Institution of Oceanography found a "living fish fossil." This was the desert pupfish which is thought to have been isolated in the area for 11,000 years since the ice age.

THE EVALUATION PROGRAM IN SECONDARY MATHEMATICS

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1. INTRODUCTION

It is the purpose of this discussion to present a brief review of the evaluation program in secondary mathematics including a survey of the various types of tests in mathematics that have been used in this country in recent years, to point out the advantages and the disadvantages of each, to discuss the progress that has been made in such tests, and to suggest better methods for their use in the future.

Only in recent years has any attempt been made to bring about genuine reform in the method of measuring the effectiveness of instruction in secondary schools—one in which the emphasis is placed upon a method of procedure rather than upon any single test itself. Moreover, whatever types of tests are recommended, each should be looked upon as a means of helping to improve the quality and effectiveness of instruction.

2. BROAD CLASSIFICATION OF TESTS

Three kinds of tests. According to the purpose which they are to serve, tests may be broadly divided into three classes: ***prognostic tests***, ***achievement tests***, and ***diagnostic tests***. Actually, the diagnostic test is sometimes considered as a kind of achievement test.

Prognostic tests. Prognostic tests are those which are usually given early in the student's career for the purpose of measuring his innate ability to do any specific kind of work. By their use a teacher is enabled to predict the probable success of a student in his later studies.

Prognostic tests in mathematics were also developed to meet the need for some kind of instrument by which to measure a student's capacity to profit by the study of some special subject, so that he might be more intelligently advised with respect to his subsequent work. Since previous tests of this type, except those relating to geometry, dealt only with the more mechanical phases of the work, mathematicians objected to them on the ground that there is little in common between habits of symbol manipulation, which were emphasized by nearly all the early tests, and the more fundamental processes of reasoning, which are characteristic of higher mathematical study. In general, they maintained that the intensive tests in special fields like arithmetic, algebra, and geometry failed of their purpose for the reason that the topics tested are rarely applied by themselves.

No one seems to have claimed that prognostic tests can be, or should be, the sole basis for prediction. Nevertheless, they constitute an important step in the direction of trying to discover those students who give the most promise in the field of mathematics. If such tests can be of assistance in discovering individual differences in mathematical ability, they may become useful instruments for prognosis in the schools. It should be insisted, however, they that must not be made the sole basis for prediction, classification, or guidance, because such absolute dependence would overlook other important factors. Moreover, there is no prognostic test available today whose use will enable us to predict success in mathematics to a higher degree of certainty than that reached by any good test which measures abstract intelligence. A student may fail to make a good showing in a prognostic test, yet his earnestness of purpose, his needs in certain lines of study, and his awakening to the interesting features of a subject may make him a worthy or, in rare cases, even a brilliant student in a subject in which the original test showed him to be weak. One difficulty is that we cannot with any certainty prognosticate what a student will do in a subject with which he has never had any contact. We can merely say that, so far as we can tell, the student is intelligently alert, and, where he has had contact with a subject, he has certain general tastes or predilections. Witness the many examples of famous mathematicians whose reaction time is very slow, or whose reputation for accurate numerical calculation is nil, or who developed their ability late in their careers, or who, in some instances at least, seem to have no space perception, that is, they are numerically minded only. Such considerations show that there is grave danger in leaving the formulation and the giving of such tests to anyone except highly trained psychologists. If such tests are wisely prepared and given, they may, of course, be useful in a preliminary grouping of a class and in helping a teacher to advise students whether to enter certain fields of work.

Shortcomings of prognostic tests. The prognostic test at its best achieves quickly and with more satisfactory results that which the schools have heretofore discovered after a loss of valuable time; at its worst it leads to a determinism that leaves some individuals absolutely without hope. On the whole, the tests have achieved a great and well-deserved success, and this success will be much more apparent when a new generation comes forward to correct the errors of the present one.

The purpose in the minds of those who have tried to devise satisfactory prognostic tests is a laudable one. If properly planned, they served to test the general alertness of a student, his general ability to reason, and his interest in the specific things with which he has come in contact.

Future value of prognostic tests. If prognostic tests could be made in such a way as to be more reliable, we should all favor their wider use in selecting those students who are most likely to profit by taking advanced work in mathematics. In that case we might require mathematics only through the ninth grade, and offer the subsequent "general mathematics" courses only to those who are capable of a much higher grade of work than is now possible. The tests could be used to advantage in determining the kind of mathematics that would be most valuable to a given student.

Achievement tests. While prognostic tests are concerned with ascertaining what a student is able to learn, it is the function of achievement tests to determine what he actually has learned. Such tests are intended to measure the progress which a student or a class is making in a given topic or course. They also measure indirectly the student's innate ability, since upon this is dependent whatever progress he may make. These tests, however, are so affected by classroom influences that they cannot be accepted as reliable instruments for the accurate measurement of the student's capacity to learn, although in general they correlate rather highly with intelligence.

There are two general types of achievement tests:

1. Those which measure separately certain specific achievements.
2. Those which yield average or general measures of a number of specific achievements within a given field.

Diagnostic tests. The first type of achievement test is called a *diagnostic test* because it points out or diagnoses the specific strength or weakness of the student. It is used mainly as a basis for finding out why a student fails in one or more particulars. Etymologically, the diagnostic test includes measurement of both strengths and weaknesses because the word "diagnostic" implies discrimination.

Diagnostic tests are, in the opinion of many, the most important tests because they quickly detect defects in a student's ability and knowledge and in methods of instruction, things connected with the learning process, about which we all are vitally concerned.

Both prognostic and achievement tests may be diagnostic in nature, although little use has thus far been made of the former in diagnosis. Furthermore, any achievement test may serve a diagnostic purpose even though the person who made it may not have so intended it, and any achievement test may also have diagnostic value and still not be used for purposes of diagnosis. At any rate, it is the purpose of the diagnostic test to find out, if possible, why a given student is unable to succeed, and to reveal strengths as well as weaknesses.

The main purpose of diagnosis is to guide the teacher in remedial instruction—that is, in remedying defects which the tests reveal. Without some plan of discovering the particular defects of a student

or a class, the work of the teacher is likely to be more or less futile.

If the proper kinds of tests are given, the progress made by students can be measured, and the norms of accomplishment thus established can be used as a guide in discovering the educational needs of future classes. In addition to this, the students assist the teacher greatly by locating not only their particular difficulties but the causes of these difficulties as well. The assistance in diagnosis rendered by the students' introspection should not be overlooked, because a student will often find the cause of a difficulty more quickly than the teacher.

Possible types of achievement tests. Two types of achievement tests have had a rather wide use in this country. The first type includes the tests set by the teacher alone or in cooperation with others who are more or less responsible for the existing course of study; the second includes the "extramural" tests set by examiners who have little or no direct contact with the classroom.

I do not intend to minimize the importance of either of these general types, especially when tests are so designed as to serve some useful purpose, but rather to encourage a wider use of certain special types and a more intelligent use of others.

I shall now discuss three types of achievement tests as follows:

1. Traditional *essay-type* examinations.
2. *Standardized* tests or scales.
3. *New-type* objective examinations.

The essay type of examination. The essay type of examination is the best known and most widely used. For the most part, it is made and given by the teacher. However, it has often been made and given by extramural boards. Although it has its virtues, it also has its shortcomings. It does not meet the requirements of a good test given later. It is probably best illustrated by what has been known to all as the final examination—the oldest known type of test. It has had its friends as well as its enemies, even though it is generally unscientific and its setting up and scoring are based largely if not solely upon personal judgment.

No one would argue that the essay type examination should be eliminated altogether. On the other hand, it is clear that marking practices on such tests are highly subjective; that is, the mark given depends to a large extent upon the person who does the marking. Furthermore, the measure obtained by the teacher from many of the ordinary essay type examinations is not truly diagnostic. It is thus clear that if specific measures for diagnosis are desired, the ordinary examination will not prove entirely satisfactory.

Tests set by the teacher. A volume of considerable size could be

written about tests set by the teacher, but space will permit only a brief statement of a few of their advantages and disadvantages. It is well known that many teachers are not qualified to make the careful analysis of the course which is necessary in determining the abilities which are fundamental and which can or should be measured. As a result, certain teachers include in their final examinations a meager sampling of the large range of abilities, and regard a few questions as an instrument for measuring the entire field. Such a procedure is unscientific and depends too much upon the judgment of one person.

It is not so easy to make a good examination as many teachers seem to think. It takes a great deal of time, energy, and thought to construct a suitable test; but there is probably no part of the work today from which more important results would follow than from taking greater interest and care in the making of tests and in evaluating the work done in the secondary school.

Teachers best qualified to do the testing. In spite of the frequent inadequacy and inaccuracy of teachers' judgments, both in setting good examinations and in marking them fairly, it should be more generally realized that these same teachers are in the long run the people best qualified to do the task. If they do not already know, they can learn not only how to make objective tests that will have both measuring and diagnostic value, but also how to use them intelligently. This ability to use the test will increase in proportion to the progress they make in understanding scientific methods of measurement. Instead of constantly reminding teachers of their failures, without making suggestions for improvement, we should direct attention rather to the traditional method of marking, the continued presence of which in the system forces its use upon teachers to the exclusion of a better method. School marks have long been used to measure a multitude of things which have not been and cannot be measured with any degree of precision.

Instead of continuing the practice of doing injustice to thousands of students every year because the tests are misused, we must in some way develop a new marking system based on more objective tests which will enable us to rate their achievements in relation to their actual ability. Probably in no part of the work today is greater care needed than in the making of tests of the right sort.

Extramural examinations. During the past half century there have been many discussions regarding the examinations set by state and college authorities. Some progress has been made in the content of these examinations and in the method of conducting them, but much remains to be done before they can be said to have reached their highest development even for the purpose for which they are designed. New York State has dictated Regents' examinations, generally good

for a poor teacher and generally bad for a good one. The College Entrance Examination Board has also, and naturally, dictated what should be taught in mathematics, and has recently made a long step in advance by a series of improvements. Each of these cases of dictation has in the past contributed powerfully to making mathematics stagnant, and each has been potent in keeping it too much on a dead level of traditional mechanism.

Everybody will readily admit that those who formulate the tests referred to above are often better able to judge what is fundamental in a course than are many classroom teachers of mathematics. In fact, the recent College Entrance Examinations and syllabi as well as those of the New York Regents suggest more modern types of mathematics courses than those which a great many teachers are now teaching. The trouble is not so much with the original purpose of such examinations as with their imperfect preparation, use, and interpretation. In many cases these examinations measure abilities which have not been considered in the previous instruction given by many of the teachers whose students have to take them, and consequently the results secured cannot be called fair measures of the teachers' effectiveness. Nevertheless, it is true that the degrees of efficiency of teachers and of classes in the same or different schools have been compared on the basis of the relative scores made on such examinations. As a result, all sorts of methods are resorted to by certain teachers whose sole aim is to get their students through these examinations with a passing grade. Such practices, it need hardly be said, do not represent a desirable type of modern education.

Opposition of teachers to extramural examinations. Extramural examinations have been opposed by many thoughtful teachers, not so much because the syllabi or a given test are so unsatisfactory, but because of the bad effects of the system. Certain heads of departments in the New York City schools have criticized the Regents' Examinations, and blame the Regents' system for poor teaching and the accompanying results. The details of these criticisms are contained in reports and comments of various chairmen of departments quoted in *High Points*—a New York City Board of Education publication. The head of one mathematics department is reported to have said that the Regents' test "establishes a false standard of values, leading a teacher to regard high marks and not mastery of the subject as the end of instruction." He adds further that it is quite possible to drill for an examination and to pass a large number of students with high ratings without giving any breadth of outlook or grasp of underlying principles.

The mere fact that there has been so much discussion about

the value of extramural examinations indicates that thoughtful people generally are not satisfied with the present character and results of such tests.

Whenever examinations, or rather the bare results of examinations, become the guiding principles for administrative action, we are getting dangerously close to fatal practices and we do injustice to the students and teachers alike. There is little question that the system of extramural examinations has led to a maximum amount of rote memory, to the extent that many students have never discovered that any other method of acquiring knowledge or developing power is possible. A boy in a certain solid geometry class made what would ordinarily be called a perfect recitation on a solid geometry theorem and the teacher had assigned a mark of "excellent" on that recitation when someone raised a question concerning the figure on the board. When answered by the boy, it showed conclusively that the figure existed for him only in the plane of the blackboard. Memory work had been his only tool for passing the courses in mathematics, and he developed the habit largely through the influence of a consistent but unwise system of tutoring outside of class. The only remedy for such a practice in any system is to have the work of students supervised. They should be taught when it is best to memorize, and when it is best to study according to some judicious and well-thought-out plan.

It is therefore evident that extramural examinations do not meet the requirements as measuring instruments. They tend to measure less of mathematical achievement and more of general intelligence. Furthermore, such examinations cannot be given to all students except at the expense of certain groups. In fact, it is easy to conceive of a situation in which one group whose preparation had been of a higher type than that of another would make a showing distinctly inferior to that of the second group simply because the examination was not based upon material to which the first group had devoted an equal amount of attention.

New-type tests. A steamboat should not be condemned because it is not an ocean liner; it was not intended to be. In the last thirty years, objective new-type tests have to a large extent replaced the essay type test in mathematics. Standardized tests in which some standard of performance has been worked out on the basis of a certain number of questions correctly answered in a certain number of minutes, have come into wide use.

Chief values of standardized tests. The chief values of standardized tests in mathematics may be summarized as follows:

1. Such tests have brought out more clearly the problem arising from individual differences in ability among students.

2. They have shown that a great deal of the traditional material is too difficult for most students and therefore should not be taught.

3. In some cases they have also shown that certain material was easier than had been expected and could therefore be mastered by a large majority of students.

4. They have justified the teacher in stopping drill for certain students beyond the stage of diminishing returns.

5. They have enabled us to develop certain standards of achievement which are clearly defined and which can be assigned to varying levels of intelligence. However, this value has occasionally been overrated.

6. They have contributed to the development of more objective methods of teaching.

7. They have, when intelligently used, stimulated students to renewed effort in trying to reach certain standards of perfection, or at any rate to improve upon their own previous records.

Disadvantages of standardized tests. Although standardized tests have been useful in the past, they have certain disadvantages. The purpose here is not to condemn standardized tests, but rather to point out and emphasize the need of more care in their construction, in their use, and in interpreting the results of their use in the classroom. It is in these three respects that the tests are open to criticism.

1. *Careless construction of standardized tests.* A great deal of the traditional arithmetic and algebra which has been questioned by teachers and textbook writers as being contrary to modern objectives has been replaced by more valuable material. It is an interesting fact, however, that standardized tests have failed to include enough of the latter type of material and thus have made difficult the general acceptance of some of the more modern courses in arithmetic and algebra. In the stage of curriculum building in which we are now engaged it has been repeatedly pointed out that it is far more important for us to get agreement on the fundamentals of a course than it is to standardize mediocrity.

A careful study of many of the standardized tests shows:

a. That they are not always adapted to the purpose of educational tests as outlined on pages 134 and 135.

b. That they cannot be easily adapted or modified to meet the needs of different courses of study or of conflicting ideas on what topics should be taught.

c. That it is difficult to adapt standardized tests so as to measure objectives which have to be secured in short periods of time.

d. That teachers tend to drill their students upon the tests themselves or make up other tests like the ones that have been standardized. In such cases an improvement in a student's score is not necessarily an index of progress in abilities tested.

The tests we need to use do not presume that every student must do a certain amount of work in a given time; they recognize individual differences. If standards are desired in a given class or school, the teacher or teachers in question should set the standard.

e. That they are sometimes prepared by people who select material with little regard to the proper objectives to be obtained and who seem to be ignorant of the latest improvements in mathematical education. Unless made by those who know how to weigh values, such tests tend to perpetuate the obsolete.

f. That there exist many desirable objectives which were overlooked when the tests were made; that is, some objectives "have no standardized tests by means of which they may be measured." Statistically the tests themselves may be perfect; but when a task is introduced into a test, as has been done in many cases, merely because it represents a certain degree of difficulty on a given scale, it simply tends to prejudice all persons of common sense against the whole movement. For example, if a test-maker has one item that turns out to have a difficulty of 40 and another one of 50, he is too often interested in getting an item that has a difficulty of 45 without any regard to its validity or value in any other sense than that of its difficulty for the student.

Examples illustrating obsolete material. The following example taken from one of the arithmetic scales on addition will illustrate what I have said above:

The problem has no relation whatever to anything that is real in the life of the student who is called upon to do the task. Moreover, it cannot be justified even from the mental discipline viewpoint because there is more valuable material that might be offered. The problem is obsolete and fictitious because in the first place no one would ever obtain such decimals as are here represented except from measurement; and none except a scientist would need to measure with any degree of precision beyond hundredths. Moreover, even if such accuracy could be obtained and one of the numbers was given correct to ten thousandths, then certainly all of the others should be so represented. It is the inclusion of such tasks in standardized tests that tends to perpetuate the obsolete in the schools.

Add
113.46
49.6097
19.9
9.87
.0086
18.253
6.04

What is true of arithmetic tests is probably ture of all the other standardized tests. Take the case of the algebra tests, where the following illustrative examples are typical of some of the worst mistakes.

Illustrative Example 1. Simplify $\sqrt{20}+\sqrt{45}+\sqrt{\frac{1}{5}}$.

This is an inherited type of example which good teachers have

been trying to get rid of for a generation past. It is difficult to imagine any real situation that would ever require it.

Illustrative Example 2. The total number of circus tickets sold was 836. The number of tickets sold to adults was 136 less than twice the number of children's tickets. How many were sold of each?

Is the cause of algebra helped by this style of problem in a test? As an interesting class puzzle it may be commended, but as a type that is to be standardized by these papers, thus being required in schools at large, it is at least not ideal.

The examples cited above are not unusual. Similar cases can be found in many standardized tests. They would be no worse here than in the textbooks if it were not for the fact that the process of standardization tends to preserve them and to perpetuate their teaching in the schools.

2. *Misuse of standardized tests.* No one today would question that the introduction of standardized tests has been accompanied in many places by grave misuse. Sometimes those in charge of the testing program are so unwise as to judge the success or failure of a teacher solely by the outcome of such tests. In other cases invidious comparisons, based on the outcome of the tests, have not been checked by a careful study of the teaching methods employed. Again, certain algebra tests have been regarded as entirely reliable when they were not, and the assumption has been made in practice that the tests can be used to measure every feature of the teaching of algebra.

Norms. When definite norms are established, there is a temptation for a teacher or a school to be too well satisfied with the achievement of a class or group of students that reaches the standard norm of performance. Such an attitude leads to standardization of mediocrity and causes otherwise good teachers to overlook the fact that the standard norms may be raised by lifting the general level of achievement through better methods of teaching. Someone has said, "The good is enemy of the best." The real value of a student's test score does not lie in the comparisons with other localities, or national norms, but in comparison with the accomplishments of other students in the same class or school system. Better still the comparison of a student's score with that of a score he made on a previous test is most valuable.

The greatest use of standardized tests. The greatest use of standardized tests in mathematics has been made in arithmetic. This has been due to the fact that the material lends itself readily to standardization. It is only fair to say that even here the tendency today is away from

general national standardization and towards practice exercises and diagnosis of individual cases. This grew out of the realization of the importance of basing a student's achievement on some definite scale of performance related to the performance of members of their own classes, rather than trying to place them with reference to a norm based upon the performance of some outside group —a practice due entirely to the influence of the recent testing movement.

The time element. Next comes the matter of the time element. Thorndike often pointed out that the speed with which a student makes errors is of no importance. Then, too, more careful thought is needed with reference to the purpose and place of the so-called speed or time-limit tests and power of work-limit tests.

The tests we need to use do not presume that every student must do a certain amount of work in a given time; they recognize individual differences and needs. If standards are desired in a given class or school, the teacher or teachers in question should set the standard. For all these reasons, standardized tests should be used more sparingly and more carefully in the future.

3. *Faulty interpretation of test results.* Some of the evils of the faulty interpretation of the results of standardized tests have been implied in what was said above about the misuse of tests. However, the worst evil in the interpretation of such results has been the tendency of teachers and supervisors to judge students adversely on the results shown by standardized tests; for example, those which tested many things that presumably the students had never been taught. Not only the students themselves but the department of mathematics and even the whole school system have been blamed for what was thought to be a poor showing. As a matter of fact, a properly constituted test, based upon what had been taught, might have placed such students and their schools in a more favorable light. Such is the reputation that comes to schools who have examinations superimposed upon them with little consideration of the validity[1] of the tests for the particular school involved.

Where standardized tests are valid and reliable instruments, they may profitably be used for purposes of *general survey diagnosis*, and even in some cases for *class and individual diagnosis;* but this work must be based more and more upon the cooperation of all concerned, even the students themselves.

In all fairness to those tests it should be said that they have gone beyond what Woody called the "curiosity" stage and "the stage in which the predominant idea was the use of tests for determining existing levels of achievement," and, in some respects at least, have

[1] See later in this article for a definition of "validity."

approached the third stage, "in which the predominant idea is the utilization of tests as a means for the improvement of instruction."

Use of standardized tests should not be obligatory. While standardized tests have been of real service in the ways that have been pointed out and therefore are to be commended for serving the purposes for which they were intended, nevertheless there are reasons at present for giving them less prominence in educational discussions and for turning our attention to a testing program that seems to offer an opportunity to obtain more important results.

What we may expect in future tests. It seems reasonable to expect that we shall in due time have tests that are prepared by those who know not only the underlying principles of these devices but also the true objectives in the teaching of mathematics. These tests can be made in such forms that they may be used not only for both general and particular diagnosis but also as aids in improving instruction. When this is done, there will follow the establishment of norms of attainment which can be generally used.

It is hardly conceivable that we shall be able to succeed as we wish unless we develop, for mass instruction, a type of teaching that is based upon the specific needs of individual classes and students. This sort of instruction should be remedial and must be based upon specific diagnostic measures of students' achievements.

The purpose of educational tests. Horn pointed out long ago the most important use of educational tests, namely, that the method of testing needs to be emphasized rather than any particular test. He listed the important purpose of educational tests which I have adapted and amplified as follows:[2]

1. To give in a brief period of time a rapid survey of all the skills or abilities to be tested. Students' difficulties with given topics are often due to the teacher's neglect to provide instruction in certain details. What is mathematically to the teacher a single skill may be psychologically to the student a complex of skills. The new-type test on the quadratic formula on a later page will bring out this point in a practical way. The old essay-type of examination tested only a few skills, and it took a long time.

The standardized test in mathematics has made little progress in this direction, although it has made a start.

2. To remove the personal equation in marking papers—in other words, to make the scoring of tests objective. The marking of examination papers in the past has been highly subjective: every teacher is

[2] Ruch, G. M. *The Improvement of the Written Examination*, General Preface by Horn, Ernest. Scott, Foresman and Company, New York, 1924.

prejudiced with respect to his students. Objective tests can be marked in only one way, and the record is necessarily impersonal. The tests given at the end of this discussion are all tests which can be scored in only one way.

3. To show the student how efficient he has been. The old essay-type of examination did not do this. It was too narrow in scope to show much of the student's mastery of the field.

4. To show the teacher how efficient he has been. The essay-type of examination can reveal only how well the teacher has taught a few things. The modern educational tests, through their diagnostic features, set forth clearly the strength and weakness of the students so that the teacher can do remedial work when necessary. This is the strongest feature of such tests. When properly prepared, they reveal the student's knowledge and abilities with respect to every essential feature of the work.

5. To measure the value of a given text or method of teaching. The tendency today is to build up a course of study and then provide tests to determine how well the objectives are being realized.

6. To find out how long it takes to teach a given topic. Today we do not know how long it takes to teach anything. We know that we are getting mastery of only a few things. With proper testing, for example, we could find out how long (approximately) it would take to teach a normal group of ninth grade students to factor the difference of two squares to any desired degree of mastery.

7. To serve as teaching devices. No textbook can contain all the exercise material required by modern courses of study, particularly in the fields of oral work and rapid written work. The tests supplement the text and relieve the teacher of the necessity of supplying additional material.

8. To find out what is a desirable content. No matter how desirable some objectives may be, it may be that some of them are not within the reach of the students. It is only by intelligent testing that we can properly decide finally which objectives are valid.

9. To enable a student to rate himself on his performance in relation to his former record or that of his fellows. The first of the two schemes is probably the better. Just as a man is eager to beat his own score in golf, so a student is usually eager to improve his score in mathematics. If he is not, we should train him to want to do it.

10. To survey the status of teaching in a school system. These tests are designed to afford a comprehensive survey of the work of a semester or a year. They are often given by someone who is surveying the school system, and although general, they are useful in indicating the status of teaching in the system.

3. The Future of Testing

Some practical suggestions for testing. Teachers are beginning to understand that a test which merely bears a test label is not necessarily one to use. If it tests what ought to be taught, or what actually is taught it will be considered a good test, otherwise it will not secure their approval.

The new-type test grew out of the feeling that teachers themselves, or at least those who are responsible for what the teachers are doing, should make the tests. The plan is to have the course of study in mathematics agreed upon first. Having done this, the next problem is to list the minimum essentials and then base the fundamental test questions on them. Thus, nothing would be included in any test which did not represent something worth perpetuating in the course.

Such tests will be truly diagnostic in that they will aid in future instruction. Too often tests have been given purely for the sake of testing or at best as a means of securing marks. Unless tests can be used principally as a basis for improving instruction then it is not worthwhile to give them at all.

Let us suppose, for example, that in teaching simple equations we shall teach only those of a certain type of difficulty—the final difficulty, however, to be determined by what the students can actually do. Let us agree that we shall try to test two things, namely, the ability to solve certain types of equations and the ability to translate certain applied problems into algebraic equations that express the conditions of the problems. It is obvious that only the writing of the equation is necessary in the second case since the student's ability to solve the equation has already been tested by a test of the first kind.

Let us further agree that $3w=12$ represents the *first type* of equation presented and that we want the student to learn to be rapid and accurate in solving this type of equation having first learned that to solve such an equation he must *divide both sides of the equation by the same number.* When the teacher feels that it is time for a test on this type he may give say sixty examples like those shown below. Probably it might be a good thing to give this list as a timed test, say two or three minutes, the time to be fixed so that only one or two of the students can finish it in the given time.

The question of time limits in tests of this nature is relatively unimportant; in fact, experience has shown that the chief value of such limits is to encourage reasonably rapid work on the part of the students. The individual differences of students with respect to speed are so great that any attempt to insist upon a standard rate is certain to be futile.

First Type of Equation

In each of the following equations solve for the letter indicated:

1. $2l=4$.
2. $3n=9$.
3. $8=42$.
4. $5t=5$.
5. $6v=6$.
6. $2n=6$.
7. $12=2n$.
8. $3a=15$.
9. $4b=16$.
10. $5p=35$.
11. $40=4x$.
12. $7y=49$.
13. $6q=66$.
14. $8n=72$.
15. $9L=54$.
16. $3a=36$.
17. $5b=70$.
18. $6y=54$.
19. $7z=63$.
20. $8c=64$.
21. $1=2b$.
22. $3c=2$.
23. $3=4n$.
24. $5a=5$.
25. $12=6a$.
26. $7a=10$.
27. $4=8y$.
28. $0.8y=4$.
29. $1.8y=18$.
30. $3=9y$.
31. $0.9y=9$.
32. $1.8=0.9y$.
33. $15=2n$.
34. $2t=21$.
35. $4=5n$.
36. $0.3n=6$.
37. $4b=5$.
38. $1.4b=2.8$
39. $13=6x$.
40. $1.6x=16$.
41. $10a=10$.
42. $10a=5$.
43. $10a=8$.
44. $20=10a$.
45. $25=10a$.
46. $12x=24$.
47. $1.2x=2.4$.
48. $1.2x=24$.
49. $12x=36$.
50. $1.2=1.2x$.
51. $3.6=1.2x$.
52. $20n=40$.
53. $10=20n$.
54. $5=20n$.
55. $25=20n$.
56. $25y=50$.
57. $50y=25$.
58. $50y=5$.
59. $36x=36$.
60. $36x=3.6$.

Further, let us suppose that three other types of simple equations are taught, namely,

Type number	*Form*	*Method of Solution*
2	$n/2+5=11$	By multiplication
3	$n-3=8$	By addition
4	$n+5=9$	By subtraction

and that tests of each of these types on the other three fundamental processes used in solving simple equations are given. Such a procedure will test their ability to do the formal part of the work with regard to both speed and accuracy.

At the end of the work on simple equations there should be a composite test made up of all the various types of equations considered essential in the course and enough similar exercises added to make the test long enough to keep the brightest students busy till the poorest ones have covered the minimum essentials included in the test. I have found it better to give this composite test at a time when the students have time to finish at least the fundamental and essential parts. The main idea here is to find out whether, after all, the students can solve all of the different types. If some of the students cannot solve all of the exercises, we want to know which exercises they

are and, if possible, why they could not be solved. It may be that the teacher will discover that his teaching has been inadequate in which case the teaching must be improved. Such tests should not be given until after the various skills included in them have been developed separately and for a long enough time to insure a high degree of mastery.

First Four Types of Equations

In each of the following equations solve for the letter indicated:

1. $2l=14$.
2. $\frac{1}{2}n=5$.
3. $n+7=13$.
4. $n-8=5$.
5. $2b=6$.
6. $2n+1=7$.
7. $2n-1=5$.
8. $\frac{1}{2}a=4$.
9. $\frac{1}{2}n+1=5$.
10. $\frac{1}{2}n-1=3$.
11. $3n+1=7$.
12. $4n-1=3$.
13. $4n-3=1$.
14. $7=4x-1$.
15. $1=4x-7$.
16. $5x-2=3$.
17. $5x-3=2$.
18. $x/2=1$.
19. $x/2+1=2$.
20. $x/5+3=7$.
21. $9x-2=7$.
22. $9x-7=2$.
23. $2x-9=7$.
24. $3x-0.9=9$.
25. $7x+2=9$.
26. $2x+7=9$.
27. $9x+1=10$.
28. $2x-1=17$.
29. $2x-0.1=1.7$.
30. $20=19x+1$.
31. $19=20x-1$.
32. $8=10x-2$.
33. $8=2x-10$.
34. $10=2x-8$.
35. $8x-2=14$.
36. $6x+0.2=14$.
37. $2x-\frac{1}{3}=6$.
38. $x/10-1=1$.
39. $3=x/10+1$.
40. $x/20+1=2$.
41. $\frac{1}{2}x+1=2$.
42. $0.5x+1=3$.
43. $\frac{1}{4}x-1=1$.
44. $0.25+1=4$.
45. $\frac{1}{3}x-2=1$.
46. $\frac{1}{5}x-0.2=1$.
47. $\frac{1}{3}x+2=3$.
48. $0.2x+3=5$.
49. $5=\frac{1}{3}x-3$.
50. $5=\frac{1}{5}x-0.5$.
51. $2=\frac{1}{4}x+1$.
52. $0=\frac{1}{4}x-6$.
53. $6=\frac{1}{4}x+6$.
54. $7=\frac{1}{3}x+5$.
55. $\frac{3}{4}x+1=12$.
56. $\frac{3}{4}x+1=3$.
57. $\frac{1}{4}x-1=1$.
58. $2x/3-1=3$.
59. $2x/3+1=5$.
60. $5=3x/4+2$.

Practice tests. In any testing program the teacher should introduce practice tests both as diagnostic instruments and as teaching devices. In fact, such tests are so important that they are fast coming to be an integral part of the better textbooks. They serve a purpose in testing specific objectives which have to be covered in a very short period of time, a function unknown to most standardized tests. Whether timed tests are to be chosen is a matter for the teacher to determine. Certainly no undue emphasis should be placed upon speed at the expense of accuracy.

Individual instruction important. It is clear that at best much time has been lost in trying to make an economical combination of mass instruction and individual instruction. As between the two, it seems evident that individual instruction should receive the greater emphasis. One great value of practice tests lies in the fact that they enable

the teacher to discover quickly the students who are in need of help, and to keep from wearying the brilliant students with work that they do not need. Furthermore, they help the student to measure his own progress in any given topic, and to be more intelligent in calling upon the teacher for assistance when this progress is not satisfactory. For the students who need to have certain skills more highly developed, practice tests are invaluable, while at the same time they enable the teacher to excuse others from practice work which might easily be come repulsive, even though *over-learning is better than underlearning.*

Value of practice tests. A large number of practice tests can and should be made for use in connection with the various topics. For example, the one on page 137 is a practice test on the first type of equation discussed on page 136. Such practice tests will save time for the teachers in the preparation of material for use in the classroom provided the textbook writers make the proper analysis of the unit skills to be developed and then include in their books enough exercises to test the student's mastery of such skills. If such tests are not included in the textbook used by the teacher, he should carefully analyze the skills that he wishes the student to master. He should then make tests to fit that analysis and use them both as teaching and as testing devices.

Many interesting and helpful things will grow out of such a procedure among which I may mention the following:

1. By checking his results the teacher has a measure of the relative performances of the students in his class. If marks must be given, this furnishes a better basis than the traditional method.

2. If the results are charted with the names of the students at the left, the numbers of the exercises at the top, and checks for right answers and crosses for wrong answers in the body of the chart, the teacher can see at a glance where the trouble has been and can then begin to introduce remedial work.

3. Not all parts of a subject, of a topic, or even of the exercises in the same simple list are equally difficult. This discovery is still to be made by some people who mark test papers.

4. Students often fail to solve an exercise not because the exercise was intrinsically too hard, or because they have been lazy, but because the teaching has not been adequate.

5. Problems may be easy enough from a mathematics standpoint but too difficult for the student as a problem in reading.

6. Certain traditional topics that have been thought too difficult for a certain grade are easily understood if the teacher presents the topic carefully. Conversely, some things that the teacher thinks are simple prove to be very difficult for certain students.

7. The right kind of thinking about some of the formal processes

in algebra may be conducive to rational thinking as well as problem solving.

The significance of such a program of testing is evident. In the first place, the teacher knows that he must be more alert in his teaching and that he must be particularly keen as to the salient points in the course. He must give tests that will help him to diagnose his own teaching situation. Thus, the teacher becomes critical of his own work and this is the way it should be. He becomes more critical of the course of study and is a more valuable asset to his associates in mathematics also in trying to make possible not only a better type of content material but also more efficient methods of teaching.

There is no good reason why a teacher who is qualified to teach mathematics at all cannot learn to formulate good tests to use in his own classes. I, for one, should favor raising the standard for teaching to insure this both in content and in method.

Finally, this better use of tests has a stimulating effect upon the student. Under the old scheme tests have been looked upon by the students as something "cooked up" by the teacher to make them work or at best as a means of marking. Since in many schools great emphasis has been placed upon marks, no end of dishonesty in taking tests has been resorted to. Often the student is conscious of no more wrong-doing than is evidenced by many grownups who make a fine distinction between stealing and "swiping." The attitude of the student is that he must "get by," as he says.

I find that students are interested in this better use of tests. They enjoy taking them because it is clear that they are testing what they should have learned. The tests are a challenge to their spirit of competition and desire to excel. The chance to cheat or even to want to do so on such a test is very small if the teacher is careful to explain the purpose of the tests and gives the student the opportunity to compete against his own former record as well as those of his classmates.

It is my feeling that such a use of tests is advisable and that it may help to usher in a new day in the teaching of mathematics.

In a subject like mathematics we can, to be sure, make many unique types of tests which will help to measure the achievement of students. Obviously, I do not have space here to illustrate each of the varieties of such tests which a teacher can make once he becomes interested in diagnostic and remedial work. Anyone who has made his own tests knows that it is a fascinating piece of work which helps the teacher to become better acquainted with his subject and to learn more about his students, so he thus becomes a better teacher.

(To be continued in a later issue.)

CHICKS ARE GOOD TEACHERS*

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Do you recall the traditional science experiences we used to have in our classrooms in which identifying objects played such an important part and where the most successful teacher was the one who knew the answers? Johnny brought rocks to school and we tried to identify them. A conscientious teacher did the best she could, but oftentimes rocks were rocks and it was always a relief when the collection went home.

Flowers were a little more interesting. What teacher didn't have a collection of flower pictures on file? Her problem of identity wasn't quite so acute. Flowers were such excellent art subjects too, and it was quite satisfying to post the children's art work, which was an outgrowth of nature study work.

But there was Tommy who troubled us. He knew Susy was always the one who got her flower picture put up and he wasn't happy over that. Tommy wasn't going to be outdone. He liked bugs. "Girls hate bugs," thought Tom, "and I bet I can get my bug picture up tomorrow." No doubt he did.

Bill contributed also. He brought a dead bird. The poor teacher would have to tolerate the specimen for half a day, and out came the picture files again. "Oh boy," thought Bill, "I sure made good claws on my picture. You can just see how my bird clings to the bough."

Well, Johnny, Susy, Bill and Tom all contributed to our science program. We hoped all were happy, that we had done the right thing for the children and, also, that we had taught the required time allotment in nature study.

It was indeed a sparse teaching of science. Facts were important and information was acquired through blind obedience.

We still maintain that facts and intellect are important but today we want to broaden the child's inherent curiosity, which is so much a part of him, and not shut it off. We attach meaning to the facts in present day teaching and we aim to teach those meaningful facts in such a way that the child grows socially and emotionally as well as intellectually and physically. Giving Johnny the bare answer to his many questions does nothing to help him live with others and not much emotional satisfaction can come out of bare answers such as we thought were so important.

How do we differ today in our approach to eager curious children so that they will experience social, emotional, intellectual and physi-

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cal growth in their learnings? If we can say to Johnny, "That's a good idea," and help him with his idea and help him in such a way that he experiences understanding, satisfaction and enjoyment, which are so indispensible in learning, and if we meet the child's needs in the right way, our teaching will have lasting significance. School ought to give opportunity to gain information and to *learn skills* for developing physical and mental health.

As an illustration of what I feel was a purposeful activity in which social interaction thrived because of the real and vital experience to the children, I wish to attempt to show how we formulated and found solutions to problems around a living learning situation in our Third Grade. It wasn't so important how much I knew on the subject but how sensitive I was to the potentialities within the experience which would help make the child easier to live with at the same time that he was learning meaningful facts.

It was autumn and two little ducklings came to visit our Third Grade Class. Fluffy and Tuffy were given much care for two days. Their arrival furnished interesting learnings such as this:

Ducks swim.
Ducks have webbed feet.
Ducks are covered with down.
Pillows are filled with down.
Ducks belong to the poultry family.
Ducks don't swallow; they wash their food down with water.

All these facts as we observed them and verified them from accurate informative sources were recorded by the teacher on a large chart, as was the new vocabulary that came from this experience.

There were questions and problems too, such as:

What do ducks eat on the farm? Bugs? Worms? Bread? Milk?
For what are ducks used?
Do we eat duck eggs?
Are ducks born?

The interest in reading stories of ducks gave a spurt to library reading. Who doesn't love "Ping" by Marjory Flack or "The Hide Away Ducklings" by Jan Flory, and all the other fascinating duck stories? Leisure time reading was off to an excellent start.

There was, however, one problem that was left standing for spring. "How Are Ducks Born?" It was agreed that the fall is not a good time in which to hatch ducks and that spring is hatching time for birds, ducks, chicks and turkeys.

When Eastertime arrived with all the excitement of the Easter Bunny and colored chicks, the hatching promise was recalled; but the

problem became more timely. Are colored chicks born colored? No one was anxious to hatch ducks but all wanted to hatch chicks. We had saved all our charts on Fluffy and Tuffy, our friends the ducklings; and some of the problems and questions again presented themselves as we began to plan for the incubation of chicks. I read the book "Trudy, The Mother Hen" by Elizabeth S. Helfman, and it formed the stimulus for deciding whether to use an incubator or a hen for the experiment. The discussions that followed on what was easiest to get and what we would get the most out of were childlike but certainly real. Someone's grandmother could furnish the hen. However, when it was discovered that there was an incubator available the children thought we ought to know about the modern way of incubation.

The incubator arrived and much discussion and planning was begun. Our major problem was, "How are we to know what is the right thing to do?" Farm journals, pictures of all kinds, informational books, were all collected and ready for use. We searched and recorded specific facts that we needed to know before our project could begin. We wrote to the University of Kentucky and the to University of Wisconsin for further information on egg incubation.

Our next step was to visit the local University Poultry Houses. With the information we had thus far obtained we were somewhat aware of the things we wished to know on our visit. We drew up plans on what we wanted to learn, such as:

1. What temperature must we keep the incubator?
2. How many eggs shall we get?
3. What kind of eggs—brown or white, large or small?
4. Where shall we buy the eggs?
5. How long will it take to hatch the chicks?
6. What must we do to take care of the eggs?

These were important problems to keep in mind and one of the children recorded them on a large chart. By now the children were recording and not the teacher.

As on any trip we were to take we had, of course, a very serious discussion on our good citizenship obligations. Since a man at the University was kind enough to take time out to help us learn all about our big undertaking, the logical thing for us to do was give him our very best attention and learn all we could. Just think—going to the University to learn about chicks! It was wonderful. There were also letters to write to the parents asking for permission.

The trip was a success, as you can well imagine. When we returned we checked our problem chart and together we recorded new vocabulary and new facts that we had learned. Now was the time for assign-

ments to be made. Stephen, a non-reader but a beautiful writer, was given the task of putting on our vocabulary chart all the new words. He took pride in this new found success; and, needless to say, his reading improved as time went on. Jane recorded facts. Thus two people already had something in common.

All had something to write about now, and I quote one—Nancy's story:

A Wonderful Visit

I went to the poultry houses and I learned lots of things. Mr. McGibbon showed us around. We went to the classroom and had a lesson. We learned that some incubators hold 500,000 eggs. He told us all about chickens that lay brown and white eggs. I know what a chicken's lobe is. After we were in the classroom we went out for some air. Then we went down the basement and saw some little chicks that just hatched. I learned that they have 4 toes and I thought they had five. Mr. McGibbon told us that ducks have bills and chicks have beaks. I felt of the little chicks tooth on top of his beak. He keeps it only three days.

We had a nice time and only two people got in trouble.

Well, you know the type of child who could write this much. You all have one or several in your room. The language of all the children flourished, however, because of our realistic experience. The spelling of new words was available on our vocabulary chart so that what the children wanted to say was not hampered by lack of spelling ability.

Our next problem was getting the eggs. Brown or white, little or large was not important any more but the word fertile was taking on new meaning and significance. All had had a chance at candling eggs at the poultry houses and seeing the germ spot, and here began their first vague biological generalization that the germ is a seed that comes from the father. An egg that has this seed is a fertilized egg.

Now began our arithmetic computation. We had no money, and eggs cost money. Egg markets were checked and every child knew the price of eggs. The suggestions on obtaining the eggs were most interesting, "We can each bring an egg from home" said slow-thinking Ann, "and if my egg hatches I can keep that chick." Strong protests broke loose on that. Others volunteered solutions such as, "We can each bring a nickel to pay for the eggs." "But who will get the chicks?" "Mr. McGibbon can give us two dozen eggs and we'll give him the chicks." "No, that wouldn't do. Chicks are worth more than eggs." "Maybe we could sell the chicks and pay Mr. McGibbon when they are sold." We telephoned the poultry houses to find out the cost of fertile eggs and the price of chicks. Why was there a difference in the prices of eggs? Arithmetic problems became very realistic. Addition and subtraction, multiplication and division were not mere facts but were related to something real and vital which made a difference to each child because we were to pay for our own eggs. The understanding of where to get these eggs was also significant.

It was indeed a big day when the precious eggs were being placed in the incubator. First the candling, then the marking of each egg with an "*x*" on one side and an "*o*" on the other, and finally the watering which was so important. Oatmeal boxes, electric light bulbs, a sprinkler top and bottle, magnifying glasses and all informational material had all been collected. Different committees took care of various tasks. The hypothesis had been carefully studied. The embryo which would develop from the germ spot needed air, water and warmth. Something like magic was to take place inside of each egg. If all conditions were right we would see, at the end of about 2½ days, a sac-like skin grown around half of the yolk. This sac would be attached to what would become the stomach of the chick. After three days we would see the sac completely surrounding the yolk. No wonder the thermometer was checked and re-checked. This brought us into room temperature and body temperature in contrast to incubation temperature.

Human relations had already manifested themselves in all aspects of this undertaking. There was a general good feeling amongst the class when the custodian offered to turn the eggs and to sprinkle the eggs generously at night and early each morning, not to forget, of course, checking the temperature. "Gee, I didn't know he was that nice," was one of the remarks heard. What I had attempted to get across in helping keep our school neat and clean took shape in the children's mind—working together made our school a better place to live in. The custodian's place in our school was not apart from us. We all wanted our school to be a good school.

Our vocabulary and concepts were developing fast. Stephen was very busy keeping up the vocabulary chart. Air cells, humidity, embryo, fertile, germ spot, sac, ventilation, and many other new terms began to take on full meaning.

Responsibilities were delegated. Committees were formed and "taking turns" became quite the accepted feeling. To watch the loving care with which the eggs were sprinkled and turned each day would have warmed your heart. Facts were checked and recorded with a careful business-like ability such as only eight-year-olds can exhibit.

Our most accurate sources of information on the development of the embryo were the books called, "From Chick to Egg" by Selsam and "The Wonderful Egg" by G. Warren Schloat.

Opening the *first* egg for inspection was an occasion filled with curiosity and apprehension. We tapped one entire side of an eggshell and with tweezers carefully removed chips, tearing the membrane away until the side of the embryo was exposed. This was the children's first direct observation of the embryo in the shell. We dropped

the contents very carefully into a dish and we viewed the specimen through magnifying glasses. What we saw was carefully recorded and then checked with our information materials.

The recording of facts developed into the idea of reporting and putting out a daily newspaper. Each day as the calendar was checked off more news developed, so we chose three reporters for each day and together they put out "The Daily Chick" on a large chart paper. Pupils were expressing themselves freely as individual thinking was engendered through the stimulating activities. It was my responsibility to exercise guidance and to open possible avenues of procedure. Meanwhile reading was flourishing. Books ranging from farming to ducks, chickens, birds and turkeys were placed on shelves according to difficulty so that each child could find reading within his own ability. Together we laughed over books like "Horton Hatches The Egg" by Dr. Seuss, or "Scrambled Eggs Super" by the same author. Watching a child chuckling over "Chicken Little" by Margaret Wise Brown or "Kip, A Young Rooster" or "The Brave Bantam," "Seven Diving Ducks" and others, made me realize that here was science that did more than give the child a casual study or busy work. An affinity was being established between numerous understandings and concepts. There was being developed in the pupil a clearer and more immediate understanding of cause and effect relationships in all growth of life. Thus, as the days of incubation progressed, all phases of our problematic activities began to be crystalized learnings in the children's minds—both social and scientific learnings.

As the last week of incubation was approaching there was a need, I thought, to study the embryo closer than through the candling process. The children realized now that the embryo was very much alive and very much developed. I opened the discussion on whether to break an egg again or not. Repercussions followed. "Do we have to break another egg? We broke one to look at and if we break another we won't get very many chicks," was Susy's lament. She wanted lots and lots of chicks. "If we open the egg now we'll kill something alive." "—and that would be sinning" was Jimmy's reaction to the suggestion. Dick didn't agree it would be a sin. "We aren't hatching chicks to see how many we get. We are hatching them to see how much we can learn." Dick further defended his point of wanting to see the embryo by stating stoutly that at the University they experiment with rats and guinea pigs so as to learn more about diseases and we had a right to look, even tho the embryo would not live long when it became exposed to the air. If the egg was a good egg and if the embryo had had sufficient humidity, accurate temperature and correct care, we would now see an almost full grown chick well formed and alive that soon would peck his way out of his shell. The news reporters

had, indeed, a very busy day—in fact, so busy that the three were excused from all classes in order to get the paper out on time.

When the incubator was closed for the hatching there was much talk on how the chick was to get out of the shell. It was recalled that Mr. McGibbon had told the children about the one tooth on the chick's beak which he uses to peck his way out of the egg—the only tooth a chicken ever has, and one which he loses after three days. During our expectant waiting we began our plans on how to care for the chicks. We drew up careful plans taken from reliable sources like the publications from the University. By the 21st day all was in complete readiness. We obtained two large paper boxes—not too deep—and two colored light bulbs for heat. We used goose-necked study lamps which could be adjusted very easily. Over the opposite end of the box we placed canvas, thus shutting out cold air from the room.

Eager, expectant faces arrived at school the morning hatching was to begin. Each child was completely satisfied as he saw the triangular shape break in several eggs just below the glass. Taking turns predominated all day. By afternoon hatching was progressing beautifully and everyone became a reporter. All wrote and expressed their feelings. I am sure that Jean must have read during those days of waiting that interesting Cadmus Book called "Chicken World" by E. Boyd Smith because she wrote a delightful story of a mother hen who had a terrible time teaching one little rascal the principle of digging worms. And her story concluded thus—"When he grew up he was a fine, bold and daring rooster who was the best crower on the farm. When he got old he was somebody's rooster dinner."

Then there was excitable Carol who wrote only this, "I'm so excited. Everyone is excited. Even Mrs. Z is excited. Oh here comes another. Oh, Oh, I'm so excited. Oh boy—they're all coming."

Sedate Ellen expressed herself this way: "Today I am so happy. A chick has hatched. I took my turn peeking through the ventilation holes. When we flashed the light on him he moved away. Now the little thing is asleep. I hope he gets a good sleep. All the teachers in school have been coming in to take a look, too. I guess they are excited like I am. Anyway I think so."

Danny went poetic:

> Baby chicks go peep, peep, peep
> And when they are older they cheep, cheep, cheep
> Baby chickens are cute little things
> Although they have very small wings.

Pat took a look and said "It's down looks like wet straw;" and she settled down to read "Gwendolyn, The Goose" by John Calvert.

Twenty yellow chicks hatched—none colored. All went to live on Roger's farm after a week of tender, tender care.

In this hectic world of jets and rockets and atoms, let us help the child to feel secure with his own thoughts. Simple learning element added to simple learning element will take the child into a larger understanding and deeper interpretation and thus strenghten him for the difficult task involved in growing up. Let's supply him with something that meets his needs and something of lasting significance such as Catherine Marshall expresses in her book "God Loves You:"

Things I like best
are little things,
Like baby birds
and fluffy chicks,
The puppies down the street;
A shiny rock,
My little jeep,
The buttercups we pick;
A baby calf,
Some kittens,
Our playhouse just so big.
Jesus, You were little once,
You know how it is.
Thank You, God For Little Things!

WANTS TOBACCO CONTROLLED LIKE ALCOHOL AND DRUGS

Tobacco should be put under the same kind of Federal regulations that now protect consumers of alcoholic beverages and drugs. And the tobacco industry should support efforts to have this done.

So declares Dr. Alton Ochsner, New Orleans surgeon and lung cancer specialist, in his book, *Smoking and Cancer: A Doctor's Report* (Julian Messner, Inc.).

Death from lung cancer at about the age of 55, if you have not died earlier from something else, is only one of the risks of tobacco smoking, Dr. Ochsner points out.

Quadruple amputation, that is amputation of both hands and both feet, or perhaps both legs and both arms, is another risk to the heavy smoker which Dr. Ochsner warns of.

Here are others: Death from heart disease. Death from a circulatory ailment. Death from an apoplectic stroke due to cerebral hemorrhage. Blindness from nicotine amblyopia.

"There are even indications that if you are a man, you may become impotent; if a woman, sterile, " Dr. Ochsner states.

Loss of sense of taste and smell, nervousness and irritability, bad digestion, and diseases of the nose, throat and voice box and asthma are still other results of heavy smoking.

Dr. Ochsner thinks there should be no tobacco smoking at all. Moderate and light smoking, he points out, are only slightly less dangerous than heavy smoking.

He does not, however, urge complete Federal prohibition of tobacco, like the alcoholic beverage prohibition of the 1920's. But he thinks cigarettes should be properly labelled, as alcoholic beverages and drugs are, so that the smoker will have the "information about the active poisons in tobacco to which he is entitled."

Cigarette advertising, he says, should warn smokers against the dangers of tobacco abuse, as alcoholic beverage advertising warns drinkers.

Testimonial advertising should be outlawed completely by the industry, he advises.

ALUMINUM'S ANNOYING ASSOCIATE

B. CLIFFORD HENDRICKS
Longview, Washington

Judge James A. Fee recently awarded over $14,000 damages in a suit brought by an Oregon dairyman. The litigation was over fumes from an aluminum reduction plant. The dairyman claimed he had sustained fume annoyance and damage to the extent of some $43,000 and that the fumes had come from the reduction pots of the aluminum plant.

The judge qualified his decision by the statement, "Evidence shows that corrective measures, taken by the company, are effective and so the defendant will not be restrained in the future operation of its plant." Federal Judge George H. Boldt in a later decision commented, "Aluminum is considered important to the economy and security of the nation . . . (Recent) installation of . . . fume control improvements (does not justify) . . . the finding of nuisance nor granting of relief (under current operational procedures)." However, the farmer neighbors of the plants in litigation still contend "The judge's important metal has an annoying associate in its production which we consider a hazard to our industry."

A FLUORIDE FUSION

The story of aluminum's extraction from its ore reveals an innovation in electrical reduction. Before its discovery isolation of a chemically bound metal by use of electrical reduction pre-supposed it as a constituent of a water soluble compound. From this water solution the metal was freed at the cell's negative pole. For metals of extreme activity the plate-out was from a dry fusion of the compound. Aluminum yielded to neither of those patterns. The final successful trial, that brought electrically produced aluminum, used a fused aluminum-bearing mineral, cryolite, as a solvent instead of water. Cryolite is a compound of sodium and aluminum and fluorine, a fluoride, found exclusively in Greenland. The ore dissolved in its fusion is another aluminum-bearing mineral, aluminum oxide, called alumina. This oxide is prepared from the naturally occurring bauxite by heating that drives water out of its composition. The free aluminum resulting from the treatment comes from this oxide and not from the fluoride.

The chemistry of the cell's action would produce metallic aluminum at the negative pole and either carbon monoxide or carbon dioxide at the other terminal of the cell's circuit. Toxic effects, presently to be considered, are not those characteristic of the poisonous carbon

monoxide but rather that would be expected from fluoride ingestion. This then diverts attention from a chemical change induced by electrical decomposition to one by heat decomposition in the cell maintained at 1000°C. temperature. It appears that the solvent, cryolite, does not entirely withstand the energy that deprives its associate, aluminum oxide, of its metal. However, evidence supports the inference that the element, fluorine, is not the annoying fume but rather its compound hydrogen fluoride.

Fluorides in Feed

Why do dairymen bring suits against fluorides in fumes? Wisconsin, a well known diary state, proposed to do more than talk about it. Their experiment station[1] set out to experimentally probe the accusation that fluorides in feed is damaging to dairy cows. Using a herd of eighteen heifers, they subjected them to a four year trial of controlled feeding. Each feeding unit consisted of three cows. Some of these units were issued rations of predetermined fluoride content in the form of rock phosphate. Others were used as controls. In brief, the findings were: If the fluoride intake was in excess of three ten thousandths of one per cent of the cow's body weight, damage was evident. Some symptoms of that effect were: loss of appetite, decrease in milk production and pathological effects in the form of teeth impairment and bone malformation. In essence, its presence in cow feed is a proven hazard.

Fluoride Fumes

Fluoride containing solids was not the basis of litigation in Judge Fee's court decision. That case had to do with airborne poison. Getting evidence of air pollution, to a degree that pasturing cattle suffer, involves an appreciably different approach. Such a study was set up, jointly[2] by the state colleges of Oregon and Washington. They sought to detect: fluorides in the atmosphere, the absorption of airborne fluorides by plants and the injury of such absorbed fluorine to plants and animals. The indicators used, to test air contamination, were: buckwheat, cabbage and collards. These plants seem to be quite sensitive to fluorides fumes in air. This investigation also sampled the cattle in the area for evidence of fluoride injury. The overall conclusion from the study was that fluoride damage to livestock and crops, in the area studied, was negligible for the two years of the investigation. The reduction plant whose fumes would have been responsible for such injury, had it been found, had installed "fume

[1] University of Wisconsin, Research Bulletin 123. (1934.)

[2] Summary Report of Fluorosis Investigation in the Sauvie Island Area in Oregon from December 1, 1951 to June 30, 1953. By the Oregon State College and The State College of Washington. (December, 1953.)

scrubbers" the year (1951) the study began. Therefore, the report implicitly indicated that the installation had reduced air pollution to a safe level for that region.

Fluoride Failure

Reasoning from the known properties of the constituents of cryolite "it should last forever" as an electrolytic solvent for the alumina in the reduction cell. Records of the consumed materials in the cell's operation contradict that prediction. One authority[3] states that for every ton of aluminum metal produced 1.88 tons of aluminum oxide, a half ton of carbon and one tenth of a ton of cryolite are required. Water in a cell for the electro-refining of copper from copper sulphate should also, by the same reasoning suggested above, "last forever." In actual practice that is not so. Cell heat accounts for the vapor loss. Cryolite is not appreciably volatile at the reduction cell's 1000°C. temperature so is not analogous to the water in the copper reduction cell in that respect. However, if there were water vapor present for reaction with the cryolite at that temperature reasoning would postulate hydrogen fluoride as produced and so the poisonous ingredient of the pot fumes would be accounted for. Thus the fluoride of the reduction pot is not only an annoyance to the industry but is a disappointment to the scientist in that if fails to behave as he predicted.

The total loss of cryolite listed in the tenth ton per ton of metal produced is, very probably, not all accounted for by the fumes emitted. Reduction cells, because of carbon consumption and other impairments, have to be relined from time to time. The faulty residual carbon in the old cell contains, in each case, a fraction of the original cryolite with which it was first charged. If the removed carbon with its adhering cryolite is discarded the cryolite thus removed will have to be replaced in the reconditioned cell. This loss is undoubtedly a part of the tenth ton cited.

Textbook writers, if they mention cryolite's consumption at all, rate it is "relatively small." Some even give the impression that the cryolite in this process lives up to the reasoned expectations that it "lasts forever." That both treatments are in error is conclusively shown when a specific case is reported. There are company units[4] that produce as much as one hundred million pounds of aluminum metal per year. For such a factory the cryolite replacement needed, in terms of that production, computes to be ten million pounds per year. That loss can certainly not be rated as small. Its replacement warrants concerned attention.

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[3] Encyclopedia *Britannica*, Volume I, page 714. (1951.)

Folk-Fear of Fluorides

Annoyance due to fluorides may even disturb community reaction to other than economic matters. The addition of fluorides to drinking water is made by many communities. The purpose is to fortify children against dental decay. Care is exercised to keep the addition below one part per million. In the Pacific Northwest, through referendum vote, many communities have refused their councilmen authority to provide such treatment. The Pacific Northwest has a number of aluminum reduction plants. Many of them have faced suits over fume damage. Is it over-presumptuous to think that the association of fluorides with those damage suits has developed an unreasoned fear of fluorides in any connection?

Factory-Used Fluorides

Whatever the ultimate decision regarding fluorination of water there are services for which "aluminum's annoying associate" may be credited.

Good management turns loss into gain That management is doubly good which turns liabilities into resources. There is yet another chapter to the story of fluorides in industry. This final chapter may add detourment to the other two performances in the follow-through of aluminum's erratic associate. First act was detection, the second was detention and now helping to detour the fluorides back to useful participation in the job for which its parent, cryolite, was originally drafted. Artificial cryolite has been competing with Greenland's native mineral for some time. Man-made cryolite has not, hitherto, been prepared from the waste discards from aluminum's production. One unit[4] branch of Reynolds Metals Company now prepares, roughly, eighty five per cent of its replacement artificial cryolite from fume scrubbings and salvage from the reconditioning of spent cells. This would seem to be another case of efficient industry keeping its place in the world of competition by converting last generation's discards into this year's dividends.

[4] Longview Unit of Reynolds Metals Company, Longview, Washington.

SOUTHERN CALIFORNIA SECTION AAPT SCIENCE TESTS

The Southern California Regional Section of the American Association of Physics Teachers announces its Eleventh Annual High School Physics Test, to be given Saturday, May 14, 1955, at El Camino College, Santa Barbara, University of Redlands, San Diego, and elsewhere as in other years. Details may be secured from Professor Thomas N. Wilson, Chairman, Test Committee, El Camino College, El Camino College, California.

Julius Sumner Miller
Secretary

SOME DIRECT USES FOR SQUARE ROOT*

ALAN WAYNE
Williamsburgh Vocational High School, Brooklyn, New York

Numerical square root, as a concept and a pattern of skills, continues to be an important topic in mathematics in the junior and senior high school. It appears to be readily justifiable for its utilitarian value, whether in general mathematics, in sequential mathematics, or in applied mathematics. Moreover, it is a topic which still has "prestige value," and students seem inordinately gratified when they master it.

Motivation for learning numerical square root is best secured through the use of simple and easily understandable applications. I have in mind relationships of the form $y=\sqrt{kx}$, or $y=k\sqrt{x}$, where k is a constant. Such relationships are also useful for development and practice, and the contrast between $\sqrt{kx}$ and $k\sqrt{x}$ emphasizes the "order of operations." In addition, such relationships provide a stepping-stone to more complicated applications of square root, such as the mean proportional or geometric mean, the Pythagorean Theorem, and others.

The following list offers, in the form of formulas, some simple direct uses for square root which have been found useful and interesting to students.

1. The side S in linear units of a square whose area is A in corresponding square units is $S=\sqrt{A}$.
2. The diameter D of a circle whose area is A is $D=1.128\ \sqrt{A}$.
3. The circumference C of a circle whose area is A is $C=3.544\ \sqrt{A}$.
4. The distance D in miles to the horizon (neglecting refraction of light) visible from a sea-level height of H feet is $D=\sqrt{1.500H}$.
5. The distance D in miles to the horizon (taking into account refraction of light) visible from a sea-level height of H feet is $D=1.317\ \sqrt{H}$.
6. Neglecting air resistance, the speed V in feet per second that a body will have after falling from rest from a height of H feet is $V=8.022\ \sqrt{H}$.
7. The time T in seconds for an object to fall a distance of D feet, neglecting air resistance, when dropped from rest at a point above the earth's surface, is $T=0.2493\ \sqrt{D}$.
8. The speed V in miles an hour at which an airplane should be flown in order to correctly carry out the air maneuver known

* Part of a presentation to the Association of Mathematics Teachers of New York State, at Syracuse, N. Y., on May 8, 1953.

as the "pylon eight," starting the maneuver at the pivotal altitude A in feet, is $V=\sqrt{15.00A}$.

9. The period T in seconds (time for one swing) of a simple pendulum of length L in centimeters is $T=0.1004\sqrt{L}$.
10. The velocity V in feet per second at which sound travels through air of temperature T in degrees Absolute (Centigrade $+273$) is $V=65.73\sqrt{T}$.
11. For a wire whose cross-sectional area is A in circular mils, the diameter D in mils of the circular cross-section is $D=\sqrt{A}$.
12. The effective flue area E of a chimney corresponding to the actual flue area A is $E=A-0.06\sqrt{A}$.
13. The recommended allowance A in inches for a running fit between a shaft and its bearing, for a bearing of diameter D in inches, is $A=0.001''+0.0008\sqrt{D}$, where A is the amount by which the diameter of the shaft should be made smaller than D

In the above formulas, the constants have been given as four-place numbers—that is, to four significant digits. This allows the use of data with three-place accuracy, and the computation of results to three-place accuracy. The exceptions are the formulas numbered 12 and 13, where the computed results are governed by precision rather than accuracy.

PROBLEM DEPARTMENT

CONDUCTED BY MARGARET F. WILLERDING
Harris Teachers College, St. Louis, Missouri

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors, Each solution or proposed problem sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the department desires to serve her readers by making it interesting and helpful to them. Address suggestions and problems to Margaret F. Willerding, Harris Teachers College, St. Louis, Missouri.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Solutions should be in typed form, double spaced.

2. Drawings in India ink should be on a separate page from the solution.

3. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

4. In general when several solutions are correct, the one submitted in the best form will be used.

Late Solutions

2423. *J. W. Lindsey, Amarillo, Texas.*

2325. In November 1952 problem **2325** appeared. At that time there was a misprint in the proposal which was corrected in the March 1953 issue of SCHOOL SCIENCE AND MATHEMATICS. The solution has not appeared. The following solution is now offered:

Solve

$$x^2+y^{1/2}=17,$$
$$x^{1/2}+y^2=3$$

for values other than (4, 1).

Solution by Julian H. Braun, U. S. Army, Aberdeen Proving Ground, Md.

Solving the second equation for $y^{1/2}$ and substituting in the first equation yields

$$x_{n+1}=\left[17-(3-x_n^{1/2})^{1/4}\right]^{1/2} \tag{1}$$

where the subscripts have been attached to the x's for the purpose of iterating the roots. If the fractional exponents are eliminated by involution the equation is of the 16th degree; consequently there are 16 roots. To obtain them begin with $x_0=4$ in (1) and allowing for the two square roots and four fourth roots within the brackets yields eight of the roots. The sign of the square root of the bracketed quantity is chosen so as to give the same sign to x_{n+1} as x_n and the iteration is continued until x_{n+1} agrees with x_n to the accuracy desired. The other eight roots are found by a similar process starting with $x_0=-4$. In iterating the complex roots the following formula is useful:

$$(A+Bi)^{1/2}=\pm\left[\sqrt{(R+A)/2}+(Bi/|B|)\sqrt{(R-A)/2}\right]$$

where

$$R=+\sqrt{A^2+B^2}.$$

The results (other than (4, 1)) are as follows:

$(4.24085, 0.96988)$, $[x^{1/2}>0, y^{1/2}<0]$;
$(3.93774, 2.23257)$, $[x^{1/2}<0, y^{1/2}>0]$;
$(4.30126, 2.25254)$, $[x^{1/2}<0, y^{1/2}<0]$;
$(4.12578\pm0.12024i, -0.98428\pm0.01503i)$, $[r(x^{1/2})>0, r(y^{1/2})<0]$;*
$(4.12669\pm0.18147i, -2.24322\mp0.00995i)$, $[r(x^{1/2})<0, r(y^{1/2})>0]$;
$(-3.95442\pm0.02537i, 1.81812\pm0.54696i)$, $[r(x^{1/2})<0, r(y^{1/2})>0]$;
$(-4.28557\pm0.02428i, 1.82130\mp0.56832i)$, $[r(x^{1/2})>0, r(y^{1/2})>0]$;
$(-4.10144\pm0.16587i, -1.80901\pm0.55987i)$, $[r(x^{1/2})>0, r(y^{1/2})>0]$;
$(-4.15134\pm0.16395i, -1.81015\mp0.56290i)$, $[r(x^{1/2})>0, r(y^{1/2})<0]$.

* r denotes the real part of a complex quantity, i.e., $r(A+Bi)=A$.

2425. *Proposed by Richard H. Bates, Milford, N. J.*

Show that the sum of the first n even integers multiplied by the first n odd integers term by term in reverse is equal to twice the sum of the squares of the first n integers.

Solution by C. W. Trigg, Los Angeles City College

$$2(2n-1)+4(2n-3)+6(2n-5)+\cdots+2n(1)$$
$$=2\{2n(1+2+3+\cdots+n)-(1\cdot1+2\cdot3+3\cdot5+\cdots+n[2n-1])\}$$

$$=2\left[2n\sum_1^n n-\sum_1^n n(2n-1)\right]=2\left[(2n+1)\sum_1^n n-2\sum_1^n n^2\right]$$

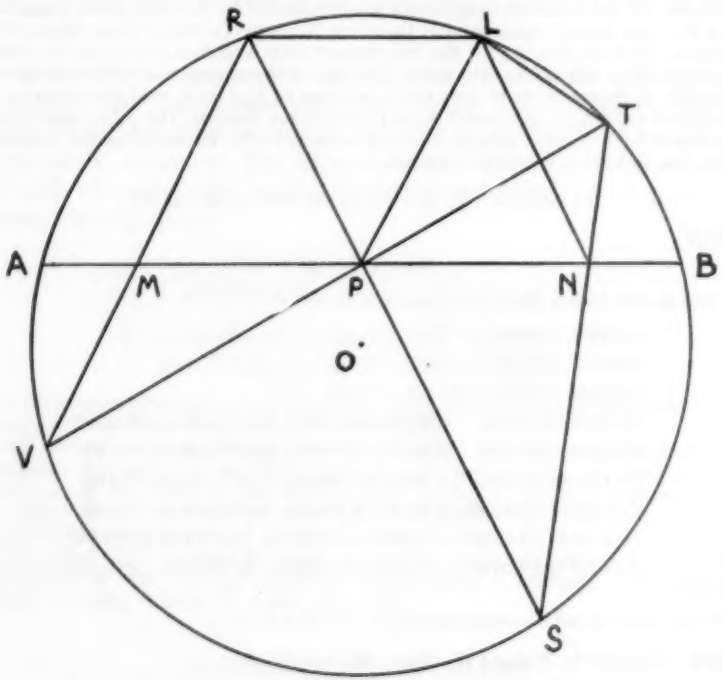
$$=2\left[\frac{(2n+1)n(n+1)}{2}-2\sum_1^n n^2\right]=2\left[3\sum_1^n n^2-2\sum_1^n n^2\right]$$

$$=2\sum_1^n n^2 \quad \text{or} \quad n(n+1)(2n+1)/3.$$

Solutions were also offered by Felix John, Philadelphia, Pa; A. R. Haynes, Tacoma, Wash.; Louis Hall, Bloomington, Ind.; John Blattner, Los Angeles, Calif.; J. W. Lindsey, Amarillo, Texas; Robert F. Steinhart, Montclair, N. J.; J. H. Means, Austin, Texas; Herta T. Freitag, Roanoke, Va.; Julian H. Braun, Aberdeen, Md., Jay Stepelman, Bronx, N. Y.; and the proposer.

2426. *Proposed by Felix John, Philadelphia, Pa.*

In circle O, P is the midpoint of chord AB. Chords RS and TV pass through point P. RV cuts AP at point M, and ST cuts PB at point N. Prove by high school geometry that MP equals PN.



Solution by Leon Bankoff, Los Angeles, Calif.

Draw chord RL parallel to AB and connect L to P, N and T. Since P lies on the perpendicular bisector of RL, we have

$$RP=PL. \tag{1}$$

Then

$$\sphericalangle PRL=\sphericalangle RLP.$$

and since RL and AB are parallel,

$$\sphericalangle RPM = \sphericalangle LPN. \tag{2}$$

Now $\sphericalangle LRS$ and $\sphericalangle LTS$ are supplementary.
But

$$\sphericalangle LRS = \sphericalangle RLP = \sphericalangle LPN.$$

Hence $\sphericalangle LPN$ and $\sphericalangle LTS$ are supplementary, and a circle can be drawn through P, N, T, L. It follows that

$$\sphericalangle PLN = \sphericalangle PTN = \sphericalangle VTS = \sphericalangle VRS = \sphericalangle MRP. \tag{3}$$

By (1), (2) and (3), triangles MPR and PNL are congruent (a.s.a.) and $MP = PN$.

Note: 1) If the diagram is drawn so that arc $AR \angle$ arc TB, the same proof applies provided that "equal" is substituted for "supplementary" wherever it appears.

2) RT and VS cut AB at points equidistant from P.

This problem was solved by W. G. Horner, of Horner's Method fame, in the *Gentlemen's Diary*, 1815, page 39. His solution is essentially as follows:

Let D and E be the midpoints of RV and TS, respectively. Since PD and PE are corresponding medians of similar triangles RVP and TPS, angle MDP equals angle PEN. (1). Now $MDOP$ and $POEN$ are concyclic quadrilaterals. So, by (1), angle MOP equals angle PON, and right triangles MOP and PON are congruent. Hence $MP = PN$.

Solutions were also offered by John Blattner, Los Angeles, Calif.; Geraldine Dolan, Detroit, Mich.; and the proposer.

2427. *Proposed by Julian H. Braun, Washington, D.C.*

Show that the principle value of arc sin $1/(1+e)$ is given by

$$\frac{\pi}{2} - \sqrt{2e}\left(1 - \frac{5}{12}e + \frac{43}{160}e^2 - \cdots\right) \qquad \text{for } |e| < 1.$$

Solution by John W. Blattner, Los Angeles, Calif.

Let $y = \arcsin 1/(1+e)$.

Then $\sin y = 1/(1+e)$, or $\cos y = \sqrt{2e+e^2}/(1+e)$, where the positive square root is taken because we are only interested in the principle value of y. We have

$$y = \arccos \sqrt{2e+e^2}/(1+e) = \pi/2 - \arcsin\left[\frac{\sqrt{2e}\sqrt{1+\frac{1}{2}e}}{1+e}\right].$$

Using a series expansion we have

$$\arcsin x = x + x^3/6 + 1/2 \cdot 3/4 \cdot x^5/5 + \cdots \qquad \text{for } x^2 < 1,$$

$$\sqrt{2e}\left(\frac{\sqrt{1+\frac{1}{2}e}}{1+e}\right) = \sqrt{2e}\left[1 + \frac{1}{4}e - \frac{1}{32}e^2 + \frac{1}{128}e^3 - \cdots\right] \cdot [1 - e + e^2 - e^3 + \cdots] \quad \text{for } e < 1$$

$$= \sqrt{2e}\left[1 - \frac{3e}{4} + \frac{23e^2}{32} - \cdots\right]. \tag{1}$$

If we call (1) x, we have

$$x^2 = [2e - 3e^2 + 4e^3 - \cdots]$$
$$x^3 = \sqrt{2e}[2e - 9/2e^2 + \cdots]$$
$$x^4 = [4e^2 - 12e^3 + \cdots]$$
$$x^5 = \sqrt{2e}[4e^2 - 15e^3 + \cdots]$$

since the series for x converges absolutely for $e^2 < 1$.

There then reults the following

$$y=\pi/2-\sqrt{2\epsilon}[1-3\epsilon/4+23\epsilon^2/32-\cdots+\epsilon/3-3\epsilon^2/4+\cdots+3\epsilon^2/10-\cdots]$$
$$=\pi/2-\sqrt{2\epsilon}[1-5\epsilon/12+43\epsilon^2/160-\cdots] \qquad 0\leq\epsilon<1$$

where we have considered only non-negative values of ϵ to give meaning to arc sin $1/(1+\epsilon)$.

A solution was also offered by H. M. Feldman, St. Louis, Mo.

2428. *Proposed by Julian H. Braun.*

Show that

$$\sec 42^\circ=-\sqrt{3}+\sqrt{5+2\sqrt{5}}$$

Solution by Leon Bankoff, Los Angeles, Calif.

$$\sec 42^\circ=\frac{1}{\cos(60^\circ-18^\circ)}$$
$$=\frac{1}{\cos 60^\circ\cos 18^\circ+\sin 60^\circ\sin 18^\circ}$$
$$=\frac{1}{\frac{1}{2}\left(\frac{\sqrt{10+2\sqrt{5}}}{4}\right)+\frac{\sqrt{3}}{2}\left(\frac{\sqrt{5}-1}{4}\right)}$$
$$=\frac{8}{\sqrt{10+2\sqrt{5}}+\sqrt{3}(\sqrt{5}-1)}$$
$$=\frac{8[\sqrt{10+2\sqrt{5}}-\sqrt{3}(\sqrt{5}-1)]}{8(\sqrt{5}-1)}$$
$$=\frac{\sqrt{10+2\sqrt{5}}(\sqrt{5}+1)}{4}-\sqrt{3}$$
$$=\frac{\sqrt{(10+2\sqrt{5})(6+2\sqrt{5})}}{4}-\sqrt{3}$$
$$=\sqrt{5+2\sqrt{5}}-\sqrt{3}.$$

Solutions were also offered by H. M. Feldman, St. Louis, Mo.; C. W. Trigg, Los Angeles, Calif.; John Blattner, Los Angeles, Calif.; A. R. Haynes, Tacoma, Wash.; J. W. Lindsey, Amarillo, Texas; and Paul H. Renton, Westbrook, Conn.

2429. *Proposed by C. W. Trigg, Los Angeles City College.*

Reconstruct the division

$$\begin{array}{l} x\,x\,)\,x\,x\,x\,x\,9\,x\,(\,x\,x\,x\,x\,x \\ \quad\underline{x\,x} \\ \quad x\,x\,x \\ \quad\;\underline{x\,x} \\ \quad\quad x\,x\,x \\ \quad\quad\underline{x\,x\,x} \\ \quad\quad\quad x\,x \\ \quad\quad\quad\underline{x\,x} \end{array}$$

Solution by the proposer

We replace the x's by other letters, using the same letter where identity of the digits is obvious. Thus

$$
\begin{array}{l}
ab\,)\,cdefg\,9\,(hijkl \\
\quad mn \\
\quad\overline{} \\
\quad pqe \\
\quad\quad rs \\
\quad\quad\overline{} \\
\quad\quad\quad t\,f\,9 \\
\quad\quad\quad u\,v\,w \\
\quad\quad\quad\quad\overline{} \\
\quad\quad\quad\quad\quad z\,g \\
\quad\quad\quad\quad\quad\overline{z\,g}
\end{array}
$$

Clearly $tf<ab$ and $j=0$. $pq+mn=pq+h(ab)=cd$, so $a\neq 9$ and $ab<90$. $k(ab)=uvw>99$, so $ab>11$. Now $100\leq pqe\leq 108$ and $91\leq rs\leq 99$. Since $uv=tf$, the hundred's digit, y, of the product $9(rs/i)$ must be such that $rs+y\geq 100$. Hence $rs>95$.

If $rs=96$, $ab=12$, 16, 24, 32, or 48. But u must be ≥ 4, so $ab=48$. Then $l=1$ or 2, $z=4$ or 9, and $w=5$ or 0, which values do not terminate any product of 48 by a digit.

If $rs=97$, $ab>90$, which is impossible.

If $rs=99$, $ab=33$. Then $z=3$, 6 or 9; $w=6$, 3 or 0, and $k=2$, 1 or 0. It follows that $uvw<100$ which is not possible.

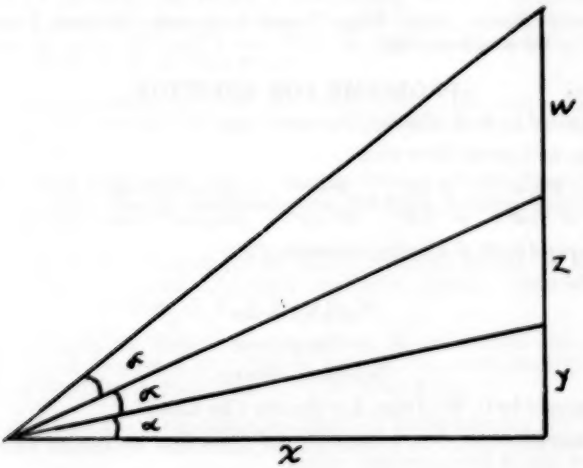
If $rs=98$, $ab=14$ or 49. But $u\geq 2$, so $ab\neq 14$. For $ab=49$, $z=4$ or 9, $w=5$ or 0. The latter value is impossible. For $w=5$, $k=5$ and we immediately complete the unique reconstruction

$$590499\div 49=12051.$$

The pattern of this problem, with 2 replacing the 9, appears as problem E971 in the *American Mathematical Monthly*, Vol. 59, p. 105–6, Feb. 1952. There also the reconstruction $591528\div 49=12072$ is unique. When the 9 is replaced by any other digit, the resulting problem does not have a unique solution.

Solutions were also offered by John W. Blattner, Los Angeles, Calif.; Julian H. Braun, Aberdeen, Md.; and J. H. Means, Austin, Texas.

2430. *Proposed by C. W. Trigg, Los Angeles City College.*



The eye of an observer standing in a ditch is level with the surrounding horizontal terrain. At a distance of x yards he observes a building y yards high, topped by a bill board z yards high, above which w yards of a vertical flag pole project. If y, z, w subtend equal angles at the eye of the observer, then (1) find x, (2) determine the limiting conditions on y and z, and (3) ascertain the smallest integer values of x, y, z, w.

Solution by the proposer.

(1) $\tan\alpha = y/x$

$$\tan 2\alpha = 2\tan\alpha/(1-\tan^2\alpha) = (2y/x)/(1-y^2/x^2) = (y+z)/x.$$

Solving,

$$x = y\sqrt{(z+y)/(z-y)} \quad \text{or} \quad y = \sqrt{z^2-y^2}/(z-y),$$

whereupon $z > y$.

(2) $$\tan 3\alpha = (\tan\alpha + \tan 2\alpha)/(1-\tan\alpha\tan 2\alpha)$$
$$= [y/x + (z+y)/x]/[1-y(z+y)/x^2] = (y+z+w)/x.$$

Solving,

$$w = (2y+z)x^2/[x^2-y(y+z)] - (y+z) \quad \text{or} \quad z^2/(2y-z)$$

whereupon $2y > z > y$.

(3) $y=3, z=5, w=25, x=6.$ $\alpha = \arctan 0.5 = 26°34'.$

Solutions were also offered by A. MacNeish, Chicago, Ill.; John W. Blattner, Los Angeles, Calif.; and A. R. Haynes, Tacoma, Wash.

STUDENT HONOR ROLL

The Editor will be very happy to make special mention of classes, clubs, or individual students who offer solutions to problems submitted in this department. Instructors are urged to report to the Editor such solutions.

EDITOR'S NOTE: For a time each student contributor will receive a copy of the magazine in which his name appears.

For this issue the Honor Roll appears below.

2425, 2428, 2429. *T. T. Gibson, Upper Canada College, Toronto*

2429. *Patrick Moran; Jack King; James Leithauser; Richard Townes; Bill Miller, all of Birmingham, Ala.*

PROBLEMS FOR SOLUTION

2443. *Proposed by R. G. Cawley, Dunmore, Pa.*

If $bx = ay$ and $cy = bz$ show that

$$\frac{x^n+a^n}{x^{n-1}+a^{n-1}} + \frac{y^n+b^n}{y^{n-1}+b^{n-1}} + \frac{z^n+c^n}{z^{n-1}+c^{n-1}} = \frac{(x+y+z)^n+(a+b+c)^n}{(x+y+z)^{n-1}+(a+b+c)^{n-1}}.$$

2444. *Proposed by R. G. Cawley, Dunmore, Pa.*

Solve the set:

$$ax+by+cz=0$$
$$x+y+z=0$$
$$bcx+acy+abz=xyz.$$

2445. *Proposed by C. W. Trigg, Los Angeles City College.*

(1) A second order determinant formed from four particular elements will have one of three absolute values.

(2) If two of the absolute values are equal, then two of the elements are equal, or one is the negative of the other.
(3) If the three absolute values are equal, then three elements are equal, or two elements are equal and each is the negative of a third.
(4) If the elements are in A.P., with $d \neq 0$, one determinant is twice another, and the value of the third is independent of the smallest element.
(5) If the elements are in G.P., with $r \neq 0$ or 1, one determinant vanishes and the ratio of the other two equals $r+1/r$.

2446. *Proposed by Richard H. Bates, Milford, N. Y.*

In a rectangle whose sides are a and b, a diagonal is drawn. If circles are inscribed in each triangle thus formed, find in terms of a and b, the length of the line of centers.

2447. *Proposed by Roy Wild, University of Idaho.*

Solve with skill $x^4-6x^3+27x+17=0$.

2448. *Proposed by Roby Fretwell, Keokuk, Ia.*

Eliminate x and y from the equation:

$$x^2y=a$$
$$x(x+y)=b$$
$$2x+y=c$$

BOOKS AND PAMPHLETS RECEIVED

TREASURY OF PHILOSOPHY, Edited by Dagobert D. Runes. Cloth. Pages xxiv +1280. 14×21 cm. 1955. The Philosophical Library, Inc., 15 East 40th Street, New York 17, N. Y. Price $15.00.

SCIENCE FOR WORK AND PLAY, Grade 1, by Herman and Nina Schneider. Cloth. 160 pages. 14.5×22 cm. 1954. D. C. Heath and Company, 285 Columbus Avenue, Boston 16, Mass. Price $1.68.

OUTLINES OF ORGANIC CHEMISTRY, Third Edition, by E. J. Holmyard, *Late Scholar and Research Student of Sidney Sussex College, Cambridge, London.* Cloth. Pages vii+492. 12.5×18.5 cm. 1954. St. Martin's Press, Inc., 103 Park Avenue, New York 17, N. Y. Price $3.50.

SAILING AERODYNAMICS, by John Morwood. Cloth. 124 pages. 17.5×24.5 cm. 1954. The Philosophical Library, Inc., 15 East 40th Street, New York 16, N. Y. Price $7.50.

NUMBERS: FUN AND FACTS, by J. Newton Friend. Cloth. Pages xi+208. 11.5×18.5 cm. 1954. Charles Scribner's Sons, 597 Fifth Avenue, New York 17, N. Y. Price $2.75.

WHAT EVERY WOMAN SHOULD KNOW ABOUT FINANCE, by Mabel Raef Putnam. Cloth. Pages xiii+254. 13.5×20.5 cm. 1954. Charles Scribner's Sons, 597 Fifth Avenue, New York 17, N. Y. Price $3.50.

EXPLORING MARS, by Robert S. Richardson, *Mount Wilson and Palomar Observatories.* Cloth. 261 pages. 13.5×20 cm. 1954. McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York 36, N. Y. Price $4.00.

AMERICAN DEMOCRACY IN MID-CENTURY. A BIBLIOGRAPHY OF RECENT BOOKS IN THE AMERICAN TRADITION, by Rychard Fink, *State Teachers College,*

Newark, New Jersey. Paper. 85 pages. 12.5×20.5 cm. 1954. The Interstate Printers and Publishers, Inc., 19–27 North Jackson Street, Danville, Ill. Price 60 cents.

WORKING WITH NUMBERS, Teacher's Edition. Books One, Two and Three, by Joyce Benbrook, *Associate Professor of Education, University of Houston; Cecile Foerster, Supervisor, Primary Grades, Houston Public Schools;* and James T. Shea, *Editorial Consultant.* Book One, 149 pages, 20.5×28 cm. Paper 48 cents, Text $1.24. Book Two, 20.5×28 cm. Paper 48 cents, Text $1.41. Book Three, 20.5×28 cm. Paper 48 cents, Text $1.41. The Steck Company, Austin, Texas.

BOOK REVIEWS

INTRODUCTION TO COLLEGE PHYSCIS, by Rogers D. Rusk, *Professor of Physics, Mount Holyoke College.* Cloth. Pages xxii+816. 15×23 cm. 1954. Appleton-Century Crofts, Inc., 35 West 32nd Street, New York 1, N. Y. Price $6.50.

In the movement toward general education, one of the trends is to make a physics course one of the requisites. Such a couse will be given to all students. One would believe it almost impossible without calculus, to present a physics course which really had "some meat in it." But to those doubters, you should examine this text. It is very complete, and doesn't even use the word calculus.

The text consists of ten units, starting with an introduction to forces, and ending with light. The sections on "Electron and Nuclear Physics" are very complete. There are many line drawings, illustrative problems, and equations. These equations are developed enough for understanding, but not so much as to become frightening or boring.

As with any new book, typographical errors creep in. Such is found on page 133, in reference to the Fig. 9–10 (c) in the text. The explanation of the jet engine was excellent, even though omitting the reason for the tremendous sound as the sound barrier is passed.

This text is not "watered down," but is interesting, informative, and soundly written. Also this text would make a valuable reference book for any high school library or physics teacher.

E. WAYNE GROSS
University School
Bloomington, Indiana

PHYSICS: A BASIC SCIENCE, Third Edition, by Elmer E. Burns, *Instructor of Physcis (Emeritus), Austin High School, Chicago, Illinois;* Frank L. Verwiebe, *Research Physicist, Applied Physics Laboratory, The Johns Hopkins University, Baltimore, Maryland;* Herbert C. Hazel, *Formerly Head of Science Department, Bloomington High School, Bloomington, Indiana;* and Gordon E. Van Hooft, *Assistant in Secondary Curriculum, New York State Education Department, Albany, New York.* Cloth. Pages xi+546. 16×24 cm. 1954. D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York 3, N. Y. Price $4.12.

This is the 1954 edition of a text first published in 1943, and revised in 1948. The format of the book is very appealing. The use of diagrams adds to the value of the text. These are clearly labelled, and placed adjacent to the manuscript describing it. The illustrations are clear and well selected.

The text consists of ten units, divided into twenty-seven chapters. These in turn are divided into eighty-three topics, each of which deals with a principle in physics. The important points are in bold face type.

The authors carry out the trend to introduce more topics than can normally be covered during a single year. This allows the teacher to select those topics which are most pertinent to his teaching situation. They have also starred some sections which may be omitted.

To the reviewer, the outstanding point of the text was the end matter. This consisted of many parts. "Check Your Understanding" was a list of new words used in the topics. "Summary Questions" were questions on the principles and facts of the topic. "General Questions" were those in which the student must apply these facts to everyday life. "Student Projects" were experiments which the students can do on their own for extra credit, or personal satisfaction. "Problems" were divided into "A" and "B" groups. These are graded, with the more difficult problems in the "B" group.

The text uses the electron flow direction, electron theory of magnetism, and includes the latest data on nuclear energy and its uses. One minor point bothered the reviewer. This was that the book should go into detail in all phases of physics, and then explain electrolysis with only, "At the positive electrode, oxygen is set free and rises . . . as bubbles of oxygen gas." This was after explaining the hydrogen came from ionized sulfuric acid.

Altogether, the text is well written and well planned. For any physics teachers contemplating a change in text, you owe it to yourself and your students to examine this text.

E. WAYNE GROSS

PLANE TRIGONOMETRY, by Paul R. Rider, Ph.D. *Professor of Mathematics Washington University.* Cloth. Pages viii+180. 14 cm. by 21 cm. 1949. The Macmillan Company, $3.00. Tables, Index, Answers to odd numbered exercises.

Plane Trigonometry by Paul R. Rider contains twelve chapters from his work, "First Year Mathematics for Colleges." The work opens with the functions of the acute angle and moves into solution of right triangles and application. Chapter 3 is given over to approximate numbers and computations. This separate chapter serves to emphasize rounding off, significant figures, scientific notation, operations with approximate numbers, and calculating machines. The next chapter contains a standard treatment of logarithm including exponential equations, change of base, and the number "*e*". Little if any previous work on this topic is assumed. Application of logarithms to the solution of right triangles follows in the next chapter.

After work on the general angle, the topic of solution of oblique triangles is presented. It is noted that this chapter contains thirty pages or about one-fifth of the total text. This amount of material is in keeping with the remark in the preface about leading the student through solution of triangles to some of the difficult phases of the subject.

The remaining chapter headings, listed in order, give a picture of the lattter part of the text: Trigonometric Formulas and Identities, Radian and Mil, Graphs of the Trigonometric Functions, Inverse Trigonometric Functions and their Graphs, and Trigonometric Equations.

FOREST MONTGOMERY
Lyons Township High School and Junior College
La Grange, Illinois

SCIENCE FOR HERE AND NOW, Herman and Nina Schneider, Cloth, 213 pages, 16.5×22.5 cm., 1954, D. C. Heath and Co., $1.92.

SCIENCE FAR AND NEAR, Herman and Nina Schneider, 279 pages, 16.5×22.5 cm., 1954, D. C. Heath and Co., $2.20.

Science for Here and Now and *Science Far and Near* are respectively the second and third grade books of a new series in Elementary Science.

Science Here and Now and *Science Far and Near* both present an excellent balance among the biological, physical and earth sciences. The two books present these areas in a readable, interesting manner. The content is accurately and clearly presented. The illustrations are colorful, well chosen, and contribute much to the understanding of the content. No doubt the illustrations will also prove valu-

able in motivating study of the many areas. Many activities apropos to the study of each area are to be found in the context of the presentation as well as at the end of the chapters. It seems that these books would help a teacher who feels inadequate in science to feel reasonably comfortable if the activities are presented as described by the authors.

The discriptions of the activity and the results of the activities should help pupils become acquainted with controlled experiments and develop their abilities to make accurate observations.

The plan of the two books appears to be aimed toward constantly expanding the childs' understanding of his physical and biological environments. The topics presented in grade 2 and grade 3 compare favorably; however, the treatment in grade 3 is more elaborate than that found in grade 2. You will find no repetitions of activities or illustrations in the two books.

The authors reveal their exceptional experience and ability in the production of these two books. The other books of the series are being awaited.

MILTON O. PELLA
University of Wisconsin

ANALYTIC GEOMETRY, by Gordon Fuller, *Professor of Mathematics, Texas Technological College.* Cloth. Pages ix+205. 15.5×23 cm. 1954. Addison-Wesley Publishing Company, Inc. Cambridge, Mass. Price $3.85.

This analytic geometry is planned primarily as a preparation for calculus. Accordingly, a few of the usual topics are not included and certain others are treated with brevity, such as, the geometry of circles.

The first chapter deals with functions and graphs and the ideas of intercepts, symmetry, excluded values, and asymptotes are considered.

A chapter is given to the use of the derivatives of polynomials and of negative integral powers of a variable. Applications are made in constructing graphs, and some maxima and minimum problems of a practical nature are included.

The elements of solid analytic geometry are treated in two concluding chapters The first of these takes up quadric surfaces and the second deals with planes and lines. Vectors are introduced and applied in the study of planes and lines. The chapter on vectors is exceptionally well done and it seemed to the reviewer to be one of the finest sections in the book.

The book contains all the basic and necessary parts of analytic geometry for a standard course in the subject. Six numerical tables are provided in the appendix. Answers to the odd-numbered problems are bound in the book.

CLYDE T. MCCORMICK
Illinois State Normal University
Normal, Ill.

MATHEMATICS IN WESTERN CIVILIZATION, by Morris Kline. Cloth. 472 pages +illustrative plates. 15×23 cm. 1953. Oxford University Press, New York, N. Y. $7.50.

Morris Kline's object in writing this book is to "advance the thesis that mathematics has been a major cultural force in Western civilization." The book was written with the lay reader in mind, but many parts, I feel, are much more interesting for the person with a mathematics background. In achieving his purpose, the author has filled the book with many interesting historical notes and personal incidences from the lives of famous mathematicians. The book is written in a chronological order, but is not intended to be specifically historical.

Mathematics is discussed as a continuing influence on culture (especially science, philosophy, art, music, literature, and religion). Topics discussing the early Greek influence; the dark age era followed by the awakening period of the Renaissance; a chapter on painting and perspective; projective geometry; the Calculus; the Newtonian influence on science and philosophy, on religion, and on literature and aesthetics; prediction and probability; the non-Euclidean geometries with their influence on philosophy, religion, and truth in general;

and one chapter on the theory of relativity represent examples of the range of coverage.

The book is fascinating and hard to put down. All mathematics teachers should read it. Probably the average high school student would find frequent places of difficulty in reading. The better high school student and certainly all college students in mathematics should find much here from which they may gain a better perspective of mathematics' role in our culture.

RALPH W. JOHNSON
Lyons Twp High School
LaGrange, Illinois

CHEMISTRY ACTIVITIES, by Robert H. Carleton, *Executive Secretary of the National Science Teachers' Association, Washington, D.C.;* John H. Woodburn, *Assistant Professor of Science, Illinois State Normal University, Normal, Illinois;* and Thaddeus H. Elder, Jr., *Formerly Chemistry Teacher, Hyattsville, Maryland.* Paper. 256 pages. 18.5×26.0 cm. 1954. J. B. Lippincott Company, 333 West Lake Street, Chicago 6, Ill.

Some call them "Laboratory Manuals," others "Work Books"; this reviewer called his "Laboratory and Study Guide." These authors have chosen well. "Activities" gets away from passivity and is more comprehensive than the other labels listed.

Learning activities may encompass appeals to three sorts of sources; things (encountered either in the laboratory or in the field), people (in interviews or in appearances before groups of learners) and books. The manual under review makes generous use of the first and last of the three.

The "Contents" lists forty eight laboratory and forty three study exercises as its program of activities. These are distributed among nine units; Matter and its changes; Nature of the elements; Structure of matter; Atoms in action; Water, solutions and near-solutions; Acids, bases and salts; Families of elements; Realm of metals; and Realm of carbon. The program not only provides content but ample suggestion for its teacher-user to gear the program for general education values and also for training students with "science potential."

In general, the activities proposed are within student experience and are presented in language fairly free from "pedageese verbage." Those sections seeking to get at scientific procedures and problem-solving, however, do have their "slips showing" at times. It is to be noted that the authors expect results from training in science's methods. They provide a separate booklet of tests for that as well as the content aspect of the course. (The reviewer would suggest that in at least two respects the sections having to do with scientific method could be improved. The word "proved" is used in many places where the word "evidence" would be more appropriate. There is an over-use of erroneous responses in the test items. It's a better philosophy for life to seek the "good" rather than the "errors.") Those, however, are minor matters in contrast with the many many original and interesting departures made from the traditional semi-cookbook pattern of exercises and experiments. There are a number of excellent high school chemistry texts upon the market but this manual is one of a very few equally good laboratory and exercise books. Teachers already stocked with a manual would find a desk copy of this one a stimulus to improved practice in their classes.

B. CLIFFORD HENDRICKS
Longview, Washington

OUR SCHOOLS HAVE PROBLEMS

They need—
More teachers—More class rooms—More money
The need is now
The situation is getting worse
There's no sign of a break

—*NAM News*

ELEMENTARY SCIENCE MEETING

The NATIONAL COUNCIL FOR ELEMENTARY SCIENCE will hold its annual meeting at the Conrad Hilton Hotel in Chicago on March 5, 1955, in conjunction with the Association for Supervision and Curriculum Development.

Dr. R. Will Burnett, University of Illinois, author of *Teaching Science in the Elementary School*, will speak on the "Spontaneity and Coherence in Elementary Science Experiences."

Glenn Blough, United States Department of Education, will serve as chairman of a panel of authors, who will discuss "Books in an Active Program of Science."

Dr. Llewelyn Heard, Standard Oil of Indiana, will present his program—"The Magic of Fire," at the luncheon.

Speakers with national reputations will lead panel discussions during the afternoon sessions.

Co-sponsoring this year's annual meeting will be the Chicago Science Teachers Association and the Chicago Catholic Science Teachers Association.

All sessions will be held at the Conrad Hilton Hotel and will include exhibits of children's projects, textbooks, and teaching aids.

Local chairman for the March 5 meeting is Muriel Beuschlein, Chicago Teachers College. Program chairman is Dr. Clark Hubler, Wheelock College, Boston, Massachusetts.

A cordial invitation is extended to all who are interested in elementary science to attend the conference and participate in the discussion group.

Conference opens at 9:30 A.M. and closes at 4:45 P.M.

For further information write to Dr. Hubler or Muriel Beuschlein, Chicago Teachers College, Chicago 21, Illinois.

NATIONAL SCIENCE TEACHERS MEETING

"More Realistic Science Teaching—Toward What Ends?" will be the theme of the 1955 National Convention of the National Science Teachers Association for all teachers of science. The meeting will be held March 24–26, 1955 at the Netherland Plaza Hotel, Cincinnati, Ohio.

Special sections for elementary science as well as high school and college will be included in the symposia, panels, clinics, and "Here's How I Do It" sessions. Thirteen work-discussion groups will provide an opportunity for every attendant to be an active participant. Educational and commercial exhibits of science teaching aids and materials will again be a feature of the convention along with a schedule of tours. Showings of science teaching films will be offered in several continuous sessions. A new program feature will be the sessions devoted to reviews of recent research in science and the implications for the use of such research results in the strengthening of teaching.

Among the speakers for general sessions are Dr. Robert Havighurst, University of Chicago, who will speak on the subject, "Science and Intelligent Choice"; Dr. Harold Fawcett, Ohio State University, who will be the guest speaker at the Saturday luncheon to be sponsored by the Ohio Science Education Association and will speak on "Science and the Nature of Proof"; Dr. Hubert N. Alyea, Princeton University, who will present one of his popular lecture demonstrations. The American Association for the Advancement of Science will be represented by by their president-elect, Dr. George W. Beadle, California Institute of Technology.

SOUTHERN CALIFORNIA SECTION AAPT SPRING MEETING

The Southern California Section of the American Association of Physics Teachers will hold its Spring Meeting at San Diego State College, Saturday, March 12, 1955.

JULIUS SUMNER MILLER
Secretary

LONGER CAR FRONTS MAY DECREASE CRASH DEATHS

Car designers might decrease the death toll from head-on collisions by putting trunk space behind the engine.

This was one of the conclusions of tests conducted by University of California scientists in which cars with dummy drivers were smashed into a reinforced log barrier. Results were recorded by instruments in the car and by a slow motion movie camera aimed at the collision point.

The experiments, which were reported to the Highway Research Board here, showed that less than one-third of the initial jolt was absorbed by the car frame. Under severe impacts the auto responds as a somewhat flexible structure.

Putting more car structure between the front bumper and the driver might increase the absorption of the impact, the report said.

The tests were run by D. M. Severy and J. H. Mathewson of the University of California engineering department.

RUBBER HOSE MOVES ORES; OUTWEARS STEEL PIPES

A newly developed hose outwears steel pipe in transporting ten-pound chunks of coal or ore.

The tubing, lined with abrasion-resisting rubber, was designed by B. F. Goodrich engineers.

Lumps of ore up to eight inches long are flushed through the hose by a high pressure stream of water from the mine to the factory and from process to process.

The new hose has proved especially useful as a substitute for pipe bands. Abrasive particles cause severe wear at turns in conventional piping systems. Unlike the pipe, the rubber hose can be rotated to distribute the wear at these points.

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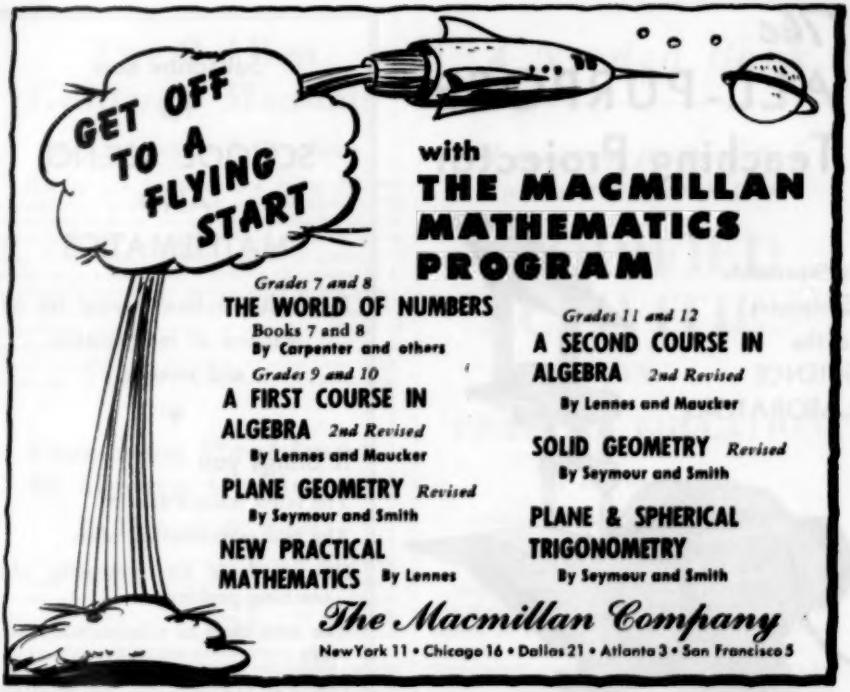

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